PROCEEDINGS OF THE INSTITUTE

REPORTS OF COUNCIL - OFFICIAL NOTICES

ANNUAL GENERAL MEETING, 1954

THE EIGHTY-FIFTH ANNUAL GENERAL MEETING OF THE IRON AND STEEL INSTITUTE was held in London on Wednesday and Thursday, 26th and 27th May, 1954, at the Royal Institution, Albemarle Street, W.1, and at the Offices of the Institute, 4, Grosvenor Gardens, S.W.1. Mr. JAMES MITCHELL, C.B.E., the Retiring President, was in the Chair at the beginning of the Meeting, his place being later taken by the Hon. R. G. LYTTELTON, the new President.

Sessions were held at 9.45 A.M. and 2.30 P.M. on the Wednesday and at 10 A.M. and 2 P.M. on the Thursday. On the Wednesday evening, a Dinner for Members was held at Grosvenor House, Park Lane.

The minutes of the previous meeting were taken as read, confirmed, and signed.

The **President** (Mr. James Mitchell, C.B.E.) began by welcoming the Members and visitors to the Meeting. He then asked those present to stand as a token of respect to Members who had died since the previous meeting, including the following:

Sir Frederick Mills, Bt., Past-President.
Mr. E. J. Fox, Hon. Vice-President.
Sir Arthur Winder, Hon. Vice-President.
Mr. E. F. Law, Hon. Vice-President.
Dr. O. Petersen, Honorary Member.
Dr. Kotaro Honda, Bessemer Medallist 1922.

The President expressed the thanks of the Institute to the managers of the Royal Institution and to the Director, Sir Lawrence Bragg, F.R.S., for permitting them to hold the meeting in their beautiful and historic building.

PRESENTATION OF REPORT OF COUNCIL AND STATEMENT OF ACCOUNTS FOR 1953

The **President** then presented the Report of the Council, published in the April issue of the *Journal*, and proposed its adoption. He stated that the Council were reasonably satisfied that the ordinary activities of the Institute were being maintained at a satisfactory standard, and they were constantly seeking ways of improving matters from the point of view of service to Members. The *Journal*, the other publications, the Library, and the information services were all of great value to Members. Good work had also been done by the Joint Committees on National Certificates in Metallurgy and Metallurgical Education. He paid a special tribute to the staff of the Institute, in particular, to the Accounts, Records, and Sales Departments.

Friendly relations had been maintained with B.I.S.R.A., the Institute of Metals, the Institution of Metallurgists, and other kindred societies in the U.K. and overseas. The valuable collaboration with the Affiliated Local Societies was especially appreciated.

A loyal message had been sent, on the occasion of her Coronation, to Her Majesty the Queen, who was Patron of the Institute, and a very gracious reply had been received. He wished to put on record their feeling of pride and thankfulness that Her Majesty and the Duke of Edinburgh had returned safely from their world tour.

In addition to the two General Meetings, held in London, a useful Symposium on Sinter had been held in the autumn and there had been a good Discussion on Boron in Steel in the spring. There had recently been a successful joint meeting with the Institute of Metals and the Société Française de Métallurgie, and he congratulated the Institute of Metals on their successful organization. The Iron and Steel Engineers Group had held a series of meetings that were well up to standard.

However, the outstanding meeting of the year had been that held in the Netherlands in October. They were extremely grateful to Mr. Ingen Housz and his colleagues (and especially to Mrs. Ingen Housz), not only for their hospitality but also for the great pains to which they had gone to make that visit a success.

The President went on to express once more the thanks of the Institute to the 45 companies that subscribed to the House Fund. As a consequence, a 60-year lease of the offices at Grosvenor Gardens had been purchased, and, in addition, £10,000 had been put aside to start a Sinking Fund. Particular thanks were due to his predecessor, Captain Leighton Davies, and to Sir Charles Bruce-Gardner for the help which they had given to the Council and to the Committee concerned.

Future meetings included that to be held in Sweden, and a joint meeting with the American Society of Metals and the American Institution of Mining and Metallurgical Engineers. Representatives of these Societies

would spend about a week in London and the provinces early in June, 1955, and then the meeting would be adjourned to Germany and France. That would be the first time that those two American societies had arranged to come to Europe, and they all looked forward to seeing them.

Mr. **R. Mather** seconded and the motion was carried.

The **Honorary Treasurer** (Mr. W. Barr) presented the Statement of Accounts. He said that it revealed a reasonably satisfactory state of affairs, in that income exceeded expenditure by £3399, which was better than the previous year. This was partly the result of increases in subscriptions, but was mainly due to the increase in revenue from the *Journal*, caused largely by the increase in advertisement revenue and sales.

The normal expenditure for the year was £68,946, which showed an increase over the previous year, due to normal increases in salaries. There had also been an increase in travelling and entertainment expenses, which reflected the increased activities of the Institute.

The most striking item in the balance sheet was the House Fund. The sum of approximately £10,000 marked on the balance sheet as being on deposit account had been invested at the end of the year. A sufficient sum would be set aside each year to ensure that, with accrued interest, the total of the amount presented by the companies, £53,700, would be replaced in not more than 30 years.

The Accounts of the Trust Funds showed an increase of income against expenditure. The sum of £500 had been transferred to the Bessemer Medal Fund so that the Medal might in future be struck in gold, as had been the case before the war.

The market value of the investments for the General Fund and the Trust Funds had increased during the year.

Mr. Barr ended by expressing his gratitude for the great assistance he had received from his predecessor as Honorary Treasurer, from the present President, and from the members of the staff.

The **President** moved, and Dr. **H. H. Burton** seconded, the adoption of the Statement of Accounts, and the motion was carried.

PRESENTATIONS

The **President** then made the following presentations:

The Bessemer Gold Medal for 1954 to Dr. T. P. Colclough, C.B.E., M.Met., of the British Iron and Steel Federation, in recognition of his distinguished contribution to the development, in theory and practice, of the manufacture of iron and steel.

The Sir Robert Hadfield Medal for 1954 to Dr. A. H. Leckie, B.Sc., of the Iron and Steel Board, in recognition of his valuable contributions to research in steelmaking.

An Andrew Carnegie Silver Medal for 1953 to Mr. G. R. Bish, formerly of University College, Swansea, for his paper, written in conjunction with Professor H. O'Neill (who was not eligible), on "The Deformation of Austenite in Relation to the Hardness Characteristics of Steel," published in the *Journal* for April, 1953.

Two Williams Prizes for 1953, of £100 each, to Mr. A. H. Norris, of John Lysaght's Scunthorpe Works Ltd., for his paper on "Soaking-Pit Practice at the Normanby Park Steelworks of John Lysaght Ltd.," published in the *Journal* for December, 1953, and to Mr. E. R. S. Watkin, of the Appleby-Frodingham Steel Co., for his paper on "Railway Traffic of the Appleby-Frodingham Steelworks," published in the *Journal* for January, 1953.

The Ablett Prize for 1953 (value £100) to Mr. F. Starkey, of Buckley and Taylor, Ltd., for his paper on "Guides and Strippers for Modern Rod and Bar Mills" (to be published later in the *Journal*).

ANNOUNCEMENTS

The **Secretary** (Mr. K. Headlam-Morley) made the following announcements:

Changes on the Council since the last General Meeting, in November, 1953:

Honorary Members of Council during their periods of office:

Dr. S. F. Dorey, C.B.E., D.Sc., F.R.S., President of the Institute of Metals, in place of Professor F. C. Thompson.

Mr. J. D. Hannah, M.Sc. (Tech.), President of the Manchester Metallurgical Association, in place of Mr. W. B. Wragge.

Mr. F. H. Saniter (who is also a Member of Council), President of the Sheffield Metallurgical Association, in place of Mr. H. Hicks.

Mr. R. E. S. Fisher, M.C., President of the Sheffield Society of Engineers and Metallurgists, in place of Mr. G. Baker, O.B.E.

Mr. K. G. Lewis, M.Sc., President of the Staffordshire Iron and Steel Institute, in place of Mr. A. W. Shore.

Retiring Members of Council—In accordance with Bye-law 10, the names of the following Vice-Presidents and Members of Council had been announced at the Autumn Meeting, 1953, as being due to retire at the present Annual Meeting:

Vice-Presidents: Mr. N. H. Rollason, Sir Charles Bruce-Gardner, Bt., and Mr. C. R. Wheeler, C.B.E.

Members of Council: Mr. H. Boot, Mr. S. Thomson, Mr. E. T. Judge, Mr. E. J. Pode, and Mr. B. Chetwynd Talbot.

No other members having been nominated up to one month previous to the meeting, the retiring Vice-Presidents and Members of Council were presented for re-election and were declared by the **President** to be duly re-elected.

Future Meetings—The Autumn Meeting would be held in London on 24th and 25th November, 1954.

The Special Meeting in Sweden would be held in June, 1954.

A Symposium on Powder Metallurgy would be held on 1st and 2nd December, 1954.

The Joint Metallurgical Societies Meeting would take place in Europe in June, 1955. The American Institute of Mining and Metallurgical Engineers and the American Society for Metals had accepted invitations from the Iron and Steel Institute, the Institute of Metals, and the appropriate societies in France, Germany, and Sweden to send representatives to a meeting in Europe in 1955. The meeting would open in London on Wednesday, 1st June, 1955. The second section would be in Düsseldorf from 9th to 12th June. A visit would be paid to Liège on 13th June. The third section would be in Paris and France from 14th to 18th June.

The **Secretary** read the following telegram sent to the Secretary of the American Iron and Steel Institute:

"*Our two Iron and Steel Institutes are meeting at the same time. We in London send cordial greetings and best wishes for a successful meeting to you all in New York. We look confidently to continued prosperity of your great industry and co-operation between our countries for the benefit of the whole free world. Greetings to you personally and come and see us soon.*"

The following was an extract from the reply which had been received:

"*Grateful for your greetings to our 62nd general meeting and want to extend our best wishes to your meeting. Concur in your hope for continued co-operation between our countries and better times for the free world.*"

BALLOT FOR THE ELECTION OF MEMBERS

Dr. **J. H. Chesters** and Mr. **E. Holland,** who had been appointed scrutineers of the ballot, reported that the following candidates had been duly elected:

MEMBERS

Abenius, Hakan (Falun, Sweden); **Adamson,** William Owen Campbell, M.A. (Port Talbot); **Akira,** Kambayashi (Yokohama, Japan); **Allmand,** Thomas Reginald (Sheffield); **Amark,** Carl Axel (Stockholm, Sweden); **Amberg,** Kurt Henrik (Stockholm, Sweden); **Andresen,** Thorual, B.A.Sc. (New York, U.S.A.); **Anjou,** Axel Åke (Ödeborg, Sweden); **Ashton,** Dennis, A.C.T.C.Birm., Wh.Sc. (Birmingham); **Bailly,** Leon, M.Inst.F. (Paris, France); **Barker,** Colin John (London); **Bell,** John Raymond (Middlesbrough); **Berman,** Abraham, M.Sc., Ph.D. (Birmingham); **Björkenstam,** Nils Gunnar (Storfors, Sweden); **Blow,** Charles Alexander (Newcastle-upon-Tyne); **Bonney,** Herbert Alfred (Rugby); **Bowen,** William Trevor (Worcester); **Brown,** Gordon Thomas, B.Sc. (Birmingham); **Brown,** John, C.B.E. (Huddersfield); **Burns,** Flight Sgt. Vincent Thomas (R.A.F., Acklington); **Busby,** H. G. Trevor (Birmingham); **Carr,** James Cecil, C.B.E., B.Sc. (Darlington); **Carter,** George C., B.Sc. (Normanby); **Caunt,** Jack Francis (Huddersfield); **Chang,** Hsing Chien, B.S., Sc.D. (Cambridge, Mass., U.S.A.); **Conradi,** Lorentz Angell (Lilleström, Norway); **Creswick,** Arthur Richard, G.I.E.E. (Newcastle-upon-Tyne); **Cuscoleca,** Otwin, Dipl.Ing. (Vienna, Austria); **Day,** Walter Harold (London); **Dick,** Gilbert, M.A. (Sheffield); **Dixon,** Victor Angus (Sheffield); **Doan,** Gilbert E., Ph.D., Ch.E. (Pittsburgh, Pa., U.S.A.); **Douglas,** Richmond (Dalry); **Ekman,** Wilhelm (Uddeholm, Sweden); **Elfström,** Nils (Fagersta, Sweden); **Evans,** Edward Thomas Kenneth, B.Sc. (Aldermaston); **Evans,** Frank Charles, F.I.M. (London); **Ferry,** John Forster, B.Sc.(Eng.) (Sunderland); **Fisher,** Edward Augustus, A.R.S.M. (Penang, Malaya); **Foldes,** Stephen, M.A., L.I.M. (Reading, Pa., U.S.A.); **Forder,** H. P., A.M.I.Mech.E. (Sheffield); **Forsberg,** Erik W. (Sandviken, Sweden); **Forslund,** Isak (Katrineholm, Sweden); **Foster,** George, A.M.I.Mech.E. (Middlesbrough); **Freeth,** William Earl, Ph.D., B.Sc. (Birmingham); **Gillott,** Sidney Richard (Sheffield); **Girardi,** Daniel J., Ph.D. (Canton, Ohio, U.S.A.); **Green,** Commander John Ivor Tennant, R.N. (Retd.), O.B.E., M.I.Mech.E. (London); **Greenshields,** Thomas (Newcastle-upon-Tyne); **Güldner,** Walther A., Dr.Ing. (Luxembourg); **Hancock,** Ronald Arthur, B.Sc., A.R.I.C. (London); **Handley,** John Edward (Rotherham); **Hannaford,** Robert Heath (London); **Hart,** Raymond (London); **Hastings,** William Warren, B.A.Sc. (London); **Hatch,** G. G., D.Sc., B.Eng. (Sorel, Quebec, Canada); **Hausner,** Henry H., D.Eng. (Bayside, N.Y., U.S.A.); **Headlam,** Christopher Grimston, M.A. (Consett); **Hervey,** Charles, M.B.E. (Sheffield); **Heyworth,** Geoffrey, A.Met., A.I.M. (Hereford); **Hofsten,** Ebbe von (Persberg, Sweden); **Hollister,** Ralph George (London); **Houghton,** Francis John, B.Met. (Crook); **Hubbard,** Donald Warren, B.Sc. (London); **Hunter,** Thomas (Swansea); **Huntingdon,** Gordon, A.Met. (Sheffield); **Icke,** James Henry (Manchester); **Ishikawa,** Hiroharu (Yokohama, Japan); **James,** Edwin E., B.Sc.(Eng.), G.I.Mech.E., A.C.G.I. (London); **Jenkins,** David Thomas (Walsall); **Johnson,** Thomas William, B.Sc. (Normanby); **Jones,** Leonard James (London); **Joseph,** Thomas L. (Minneapolis, Minn., U.S.A.); **Kamura,** Heihachi, Dr.Eng., M.S. (Fukuoka-Ken, Japan); **Kempe,** Philip Courtenay (Hamilton, Ont., Canada); **Kilby,** Donald William, A.M.I.E.E. (Stafford); **Kita,** Wladyslaw, M.Sc., A.I.M. (Sheffield); **Klat,** Elie (Cairo, Egypt); **Kosmider,** Johannes, Dr.Ing. (Hagen-Haspe, Westphalia, Germany); **Krishnaswamy,** Nadathoor R., B.Sc., B.Met. (Calcutta, India); **Leake,** Laurence Ernest (London); **Leyman,** Reginald Edwin, B.Sc. (Northrand, Transvaal, South Africa); **Lilljekvist,** Gunnar Albrecht (Avesta, Sweden); **Mabbutt,** Dennis John (Luton); **Manwaring,** David Brudenell, B.Sc. (London); **Matthews,** Abraham Philip (Port Talbot); **Mercer,** Kenneth Norman Victor (London); **Mian,** Iqbal Mohayuddin, M.Sc. (Rawalpindi, West Pakistan); **Midwinter,** Charles (London); **Miller,** Herbert John, M.Sc., F.I.M. (Prescot); **Moran,** John (Sheffield); **Moxey,** Douglas Erskine (Birmingham); **Murray,** Leslie Vincent (Birmingham); **Murray,** R. C., Ph.D., B.Sc. (Farnborough, Hants); **Neumann,** Erich, Dipl.Ing. (Werk Diemlach, Styria, Austria); **Nordenson,** Jonas Wilhelm, Dr.Phil. (Stockholm, Sweden); **Omberg,** Ture (Vikmanshyttan, Sweden); **Pashley,** Percy Raymond (Sheffield); **Paterson,** Alexander Tauran (London); **Patwardhan,** Madhao Krishna, B.Sc.(Met.) (Banaras, India); **Pendray,** Walter Oscar, B.Sc. (Eng.) (London); **Philbrook,** William O., B.S. (Pittsburgh, Pa., U.S.A.); **Pollock,** Alexander (Sheffield); **Price,** John D. (Pueblo, Colorado, U.S.A.); **Pringle,** Norman (Sheffield); **Rasmussen,** Niels Reed (Copenhagen, Denmark); **Ravenscroft,** Jack, B.Sc. (Sheffield); **Rengstorff,** George W. P., Sc.D. (Columbus, Ohio, U.S.A.); **Richards,** Glanville, L.I.M. (Neath); **Robinson,** Michael Keller (Buenos Aires, Argentina); **Robinson,** William Leslie, B.Sc., A.I.Mech.E., A.I.M. (Manchester); **Rodriguez-Pagés,** Gerardo (Buenos Aires, Argentina); **Ross,** Stuart Thom, M.S.Met.E., Ph.D. (Detroit, Mich., U.S.A.); **Rudberg,** Nils (Avesta, Sweden); **Rylands,** Ralph (Warrington); **Salmon,** John Dearman (Sheffield); **Sato,** Mizuho, D.Sc. (Tokyo, Japan); **Scharlé,** Albert (Belo Horizonte, Brazil); **Sebardt,** Carl (Sandviken, Sweden); **Smith,** George Lee, M.I. Mech.E. (Corby); **Smith,** Harry (Doncaster); **Sully,** Arthur Henry, M.Sc., Ph.D., F.Inst.P., F.I.M. (Stoke Poges); **Sundén,** Ragnar (Stockholm, Sweden); **Svensson,** Per Axel (Gothenburg, Sweden); **Svensson,** Sven Gustaf Evald (Gothenburg, Sweden); **Talbot,** George (Middlesbrough); **Tanimura,** Hiromu, Dr.Eng. (Fukuoka, Japan); **Tatterson,** George K. (Shotton); **Tholander,** Erik (Vikmanshyttan, Sweden); **Thomas,** John M., B.S., M.S.E. (Detroit, Mich., U.S.A.); **Thorneycroft,** William Ernest, B.Sc., F.I.M. (Birmingham); **Unger,** William S., Jr., B.Sc.(Mech.Eng.) (Pittsburgh, Pa., U.S.A.); **Van Den Broer D'Obrenan,** J. (Paris, France); **Wallquist,** Gunnar (Stockholm, Sweden); **Wanklyn,** P. W. B. (Ebbw Vale); **Warburton,** William Keith, A.Met., L.I.M. (Sheffield); **White,** William Ernest (Middlesbrough); **Wilkinson,** Cyril Routledge (London); **Wilson,** Andrew (Pittsburgh, Pa., U.S.A.); **Yates,** Eric Wilson (Cambuslang).

ASSOCIATE MEMBERS

Apsley, Samuel Dougan (Coventry); **Castle,** Stanley Percival (Manchester); **Challis,** William Edmund (Walsall); **Choudhary,** Shree Krishna, B.Sc.(Met.Eng.) (Jamshedpur, India); **Davies,** David Howell, B.Sc.(Hons.Met.) (Aylesbury); **Davies,** Raymond Oswald (Swansea); **Deighton,** Malcolm (Newcastle-upon-Tyne); **Denton,** Brian, B.A. (Crewe); **Drake,** John Brian (Cambridge); **Eeles,** Edwin George, B.Sc. (Birmingham); **Ferguson,** John (Chesterfield); **Harris,** John Edwin, B.Sc. (Birmingham); **Hillier,** Frank (Sheffield); **Holland,** James Read, B.Sc.(Met.Eng.) (Sheffield); **Hunter,** David Booth (Newcastle-upon-Tyne); **James,** David Benjamin (Swansea); **Jones,** Alun (Swansea); **Larcombe,** Basil (Sheffield); **McGarrity,** Thomas, B.Sc., A.R.T.C. (Sheffield); **Mathieson,** Iain M., A.R.T.C. (Glasgow); **Nicholson,** Anthony (Birmingham); **Patten,** Keith David (Newcastle-upon-Tyne); **Perry,** M. (Cambridge); **Phelps,** Leonard Arthur (Birmingham); **Regan,** Michael Colin (Newcastle-upon-Tyne); **Roberts,** Peter (Salford); **Robinson,** James Alan (Newcastle-upon-Tyne); **Singh,** Surindar (Wednesbury); **Sweeney,** Brian (Sheffield); **Taylor,** John Douglas (Cardiff); **Thomas,** Evan John (Swansea); **Watkins,** Alan John (Cambridge); **Williams,** Bruce Oswald Bernard (Cambridge); **Williams,** Ernest Wynne, M.Sc. (Toronto, Ont., Canada).

The **President** declared the candidates to be duly elected. They numbered 174 (140 Members, 34 Associate Members), bringing the total membership of the Institute to 4854.

INDUCTION OF THE PRESIDENT-ELECT

Mr. **James Mitchell, C.B.E.,** before vacating the Chair, introduced the new President, the **Hon. R. G. Lyttelton.**

VOTE OF THANKS TO THE RETIRING PRESIDENT

The **President** (the Hon. R. G. Lyttelton) then proposed a vote of thanks to the Retiring President, which

was seconded by **Sir Andrew McCance** and carried unanimously, with acclamation.

PRESIDENTIAL ADDRESS

The **President** (the Hon. R. G. Lyttelton) then delivered his Presidential Address, published in the June, 1954, issue of the *Journal*.

VOTE OF THANKS TO THE PRESIDENT FOR HIS ADDRESS

Mr. **R. Mather** proposed a vote of thanks to the President for his Address, which showed the extent to which the development of the industry had been an essential part of the development of civilization and industrial life.

Sir **Charles Goodeve** seconded the vote of thanks, which was carried unanimously, with acclamation.

SEVENTH HATFIELD MEMORIAL LECTURE

The Seventh Hatfield Memorial Lecture was delivered by Dr. **T. P. Colclough,** C.B.E., M.Met., F.R.I.C., on "Development in the Iron and Steel Industry in Great Britain during the Last Twenty-Five Years" (published in the July, 1954, issue of the *Journal*).

The **President,** in moving a vote of thaks to Dr. Colclough, said that he had shown that during the last 25 years planning and development had amounted to a second industrial revolution. He had shown that industry had not stood still in the U.K. Dr. Colclough spoke as one who had taken an active and influential part in these great developments.

Mr. **E. T. Judge** seconded the vote of thanks, which was carried unanimously, with acclamation.

PRESENTATION OF PORTRAITS TO THE INSTITUTE

The **President** stated that the Council had accepted with much pleasure three portraits presented by Mr. R. W. Evans, of the Steel Company of Wales Ltd. The portraits, painted by C. F. Harris, were of:

Mr. William Menelaus (1818–1882)
President 1875–1877
Bessemer Gold Metallist 1881
Mr. Edward Williams (1826–1885)
President 1879–1881
Bessemer Gold Medallist 1886
Mr. Edward Windsor Richards (1831–1921)
President 1893–1895
Bessemer Gold Medallist 1884.

MEMBERS' DINNER

The Annual Dinner was held at Grosvenor House, Park Lane, London, W.1, on 26th May, 1954. The Rt. Hon. HAROLD MACMILLAN, P.C., M.P., Minister of Housing and Local Government, proposed the toast of "The Iron and Steel Institute and Industry," to which the PRESIDENT replied. The toast of "The Guests" was proposed by Sir CHARLES BRUCE-GARDNER, Bt., and was replied to by the Very Rev. A. C. DON, K.C.V.O., Dean of Westminster.

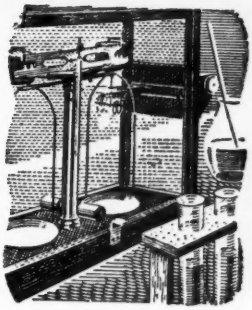
PRESENTATION OF PAPERS

The following papers were presented and discussed (the dates of publication in the *Journal* are given in parentheses):

Wednesday, 26th May
Afternoon Session
Discussion on
"Soaking-Pit Practice at the Normanby Park Steelworks of John Lysaght Ltd.," by A. H. Norris (*December*, 1953).
"Some Factors Affecting the Wear of Graphite Electrodes in the Electric-Arc Furnace," by the Electric Process Sub-Committee of B.I.S.R.A. (*February*, 1954).

Thursday, 27th May
Morning Session
Joint discussion on
"Eutectic Solidification in Grey, White, and Mottled Hypo-Eutectic Cast Irons," by A. Hultgren, Y. Lindblom, and E. Rudberg (*April*, 1954).
"Structural Changes During Annealing of White Cast Irons of High S : Mn Ratios," by A. Hultgren and G. Östberg (*April*, 1954).
"The Growth of Nodular Graphite," by M. Hillert and Y. Lindblom (*April*, 1954).
"The Solidification of Nodular Iron," by H. Morrogh (*April*, 1954).
"Undercooled Graphite in Cast Irons and Related Alloys," by H. Morrogh and W. J. Williams (*April*, 1954).
"The Solidification of Fe–P–C Alloys," by H. Morrogh and P. H. Tütsch (*April*, 1954).
"Decomposition of Cementite During Solidification of Cast Iron," by A. Berman and V. Kondic (*April*, 1954).

Afternoon Session
Joint discussion on
"New Swedish Mill Design and Layouts for Medium and Small Sections and Wire Rod," by E. Norlindh (*April*, 1954).
"The New Fagersta Wire-Rod Mill," by K.-E. Pihlblad (*April*, 1954).
"Roller Bearings in Swedish Rolling Mills and the SKF Rolling-Mill Design," by A. Leufvén (*April*, 1954).
"Practical Experience in the Use of Repeaters in a Looping Mill," by H. W. Riddervold (*April*, 1954).



Subcritical Decomposition of Carbide Phase in Some Low-Carbon Silicon Steels

By E. D. Harry, B.Sc., A.I.M.

SYNOPSIS

A brief summary of the literature dealing with the subcritical graphitization of carbon steels is given. The results of graphitization tests on three steels all containing less than 0·1% carbon and 1·8%, 2·3%, and 3·4% silicon respectively, are given. The effect of cold-reduction by rolling, annealing atmosphere, thickness of specimen, nature of surface, and silicon content are discussed. Cold-reduction of the specimen and annealing in an oxidizing atmosphere produces rapid carbide decomposition. Carbide stability decreases with increasing silicon content. 961

ONE of the most important factors affecting the graphitization of hypo- and hyper-eutectoid carbon steels is the aluminium content, but the exact way in which the aluminium influences the stability of the carbide is not agreed upon.

Austin and Fetzer[1] reported the importance of deoxidation practice, in particular the use of aluminium, on the susceptibility of a steel to graphitization. They also found that the presence of oxygen in the subcritical annealing atmosphere promoted graphitization, and attributed this effect to the formation of nucleating oxides of aluminium, silicon, etc., by internal oxidation. They noted too the effect of stresses in promoting graphite formation, but stated that compressive stresses as produced by rolling were not effective.

Hughes and Cutton[2] have also reported on the accelerating effect of deformation on graphitization and found that deformation by rolling was effective. Aluminium deoxidation was found to be of controlling importance but no information regarding the effect of annealing atmosphere was given; neither was the effect of various amounts of cold-reduction by rolling established. Jenkins, Mellor, and Jenkinson[3] found that the deformation occurring during creep testing greatly accelerated the spheroidization and graphitization of the carbide. The effect of deformation in promoting carbide decomposition has also been reported by Andrew and Lee.[4] Steels with 0·58% and 0·81% carbon content graphitized more rapidly as the amount of cold-reduction by drawing was increased to 30%. A further increase in the cold-reduction did not produce a corresponding increase in the rate of graphitization. Steels containing 0·27% and 0·16% of carbon did not graphitize whatever the amount of cold-reduction.

Smith, MacMillan, and Dulis[5] in 1951 presented results of a comprehensive investigation in which they found that when aluminium-killed steels were annealed in air or nitrogen, a carbide stable rim was formed. They concluded that this graphite-free rim was formed by the nitrogen in the annealing atmosphere combining with the aluminium to form the nitride, and furthermore that it was the residual aluminium in solid solution and not alumina or other deoxidation products which affected the stability of the carbide. In a later paper Dulis and Smith[6] stated that aluminium promoted graphitization by acting as a scavenger for nitrogen and precipitating it as aluminium nitride. Nitrogen, it was stated, either stabilized or inhibited the breakdown of cementite. The effect of austenitizing temperature on graphitization, which has been noted by numerous investigators, was said to be due to its control over the amount of aluminium and nitrogen in solution.

Dennis[7] in his report on the graphitization of aluminium-killed steels supported the nucleation theory. He found that an oxidizing atmosphere during the subcritical anneal had a remarkable effect in promoting graphitization and concluded that grain-boundary diffusion of oxygen occurred during the actual subcritical anneal at 650° C. with the formation of alumina dispersions which were eminently effective as nuclei for graphite formation.

Brown and Hawkes,[8] investigating the decomposition of carbide in cast iron, interpreted their results as showing that hydrogen, when used as the annealing

Manuscript received 21st April, 1954.
Mr. Harry is with The Steel Company of Wales Ltd., Newport Division.

Table I
COMPOSITION OF STEELS USED

Steel	C, %	Si, %	S, %	P, %	Mn, %	Ni, %	Cu, %	Al, %	N_2, %
3·0% Si	0·056	3·43	0·007	0·012	0·13	0·038	0·062	0·003	0·003
2·3% Si	0·051	2·31	0·027	0·027	0·23	0·040	0·045	0·022	0·0064
1·8% Si	0·085	1·83	0·027	0·024	0·27	0·033	0·050	0·014	0·0082

atmosphere, had a stabilizing effect on the carbide and inhibited graphite formation during all five possible stages of its formation. Palmer[9] also has reported that the presence of hydrogen in the annealing atmosphere retarded the rate of carbide decomposition in malleable cast iron.

Evidence in support of the theory of Dulis and Smith[6] on the stabilizing effect of nitrogen on cementite has been given by Dawson, Smith, and Bach,[10] who found that nitrogen introduced into cast iron by means of ferrocyanides and cyanides had a strong stabilizing action on massive cementite and pearlite.

It is agreed that:

(1) Deformation promotes graphitization although the information on the effect of varying amounts of deformation is small

(2) The presence of small amounts of aluminium in the steel has a fundamental effect on graphitization, but there are two contradictory theories offered to explain it, *viz.*, (i) the heterogeneous nucleation theory, and (ii) the theory of cementite stabilization by nitrogen.

The effect of oxidizing conditions in the annealing atmosphere has been reported by some investigators and not by others. A carbide-stabilizing effect has been attributed to hydrogen by some authors working on cast irons.

EXPERIMENTAL RESULTS

Some tests carried out on the formation of graphite in low-carbon high-silicon steels containing only small amounts of aluminium may add to the information already available on the subcritical graphitization of carbide. The compositions of the steels used are given in Table I.

The steels were in the form of hot-rolled strip at a thickness of 0·088 in. The carbon was present in these steels as pearlite.

The subcritical anneals were carried out at 600 ± 5° C. in an electrically heated tube furnace. Dried cylinder nitrogen, dried cylinder hydrogen, and vacuum were used as annealing atmospheres for various tests. Test pieces were suspended in the furnace, were removed at intervals, and specimens were cut off for metallographic examination; the test pieces were then replaced for further annealing. This process was repeated until graphitization was complete. Care was taken that the newly sheared face of the specimens was the one prepared for examination.

The annealing atmosphere had a profound effect on the graphite formation in cold-rolled samples of the 3·0% Si steel. The cylinder-nitrogen atmosphere, which, of course, contained a small amount of oxygen, produced rapid graphitization. The results are shown in Table II.

The samples in Table II were degreased before annealing but were not pickled. After annealing in the cylinder nitrogen all the samples had an appreciable amount of scale.

To investigate the effect of the amount of cold-reduction on the time required for complete graphitization, samples from the 3·0%, 2·3%, and 1·8% Si steels which had been cold-reduced 10%, 20%, 40%, and 60% by rolling in a laboratory 4-high mill were pickled to a common thickness of 0·030 in. Specimens were then annealed in cylinder nitrogen at 600° C. The results are shown in Table III, and it will be seen that whereas the as-hot-rolled sample showed practically negligible graphitization after 100 hr., the sample cold-reduced 10% graphitized extremely rapidly. However, increasing the amount of reduction above 10% actually decreased the rate of graphite formation.

Tests on the effect of specimen thickness were made on 3·0% Si steel samples cold-reduced 20%, and on 2·3% Si steel samples cold-reduced 10%. Specimens were pickled from the as-cold-reduced thickness to 0·060 in., 0·040 in., and 0·030 in. and were then graphitized in cylinder nitrogen. The results given in Table IV show that the time for complete graphitization increased with the thickness of the specimen.

The nature of the surface of the specimen had an effect on the time for complete carbide decomposition. Thus a specimen of 3·0% Si steel, cold-reduced 20% and graphitized without any pickling of the surface, was completely graphitized after 16 hr., whilst another specimen, identical except that 0·002 in. was pickled off each surface, was completely graphitized after 12 hr.

Annealing of a cold-reduced specimen in hydrogen before the graphitizing anneal in nitrogen had the effect of increasing the time required for the completion of the carbide decomposition.

The results of these graphitizing tests on low-carbon Si steels show that the carbide phase is very readily

Table II
EFFECT OF ANNEALING ATMOSPHERE ON GRAPHITIZATION OF 3·0% Si STEELS, 0·064 in. THICK AND COLD-REDUCED 20%

Atmosphere	Results
Hydrogen	Only occasional graphite nodules after 120 hr. annealing
Cylinder nitrogen (slightly oxidizing)	Completely graphitized after 15½ hr. annealing
Vacuum	Only occasional graphite nodules after 120 hr. annealing

Table III

EFFECT OF PERCENTAGE COLD-REDUCTION ON TIME REQUIRED FOR COMPLETE GRAPHITIZATION OF 0·030-in. THICK SPECIMENS OF 3·0%, 2·3%, AND 1·8% Si STEELS

Steel	Reduction, %	Result
3·0% Si	0	Only occasional nodules after 100 hr.
	10	Completely graphitized in 3 hr.
	20	„ „ „ 5½ hr.
	40	„ „ „ 9 hr.
	60	„ „ „ 15 hr.
2·3% Si	0	Only occasional nodules after 100 hr.
	10	Completely graphitized in 8 hr.
	20	„ „ „ 15 hr.
	40	Trace of carbide left after 36 hr.
	60	Considerable carbide left after 56 hr.
1·8% Si	0	No graphite after 100 hr.
	10	Completely graphitized in 30 hr.
	20	„ „ „ 70 hr.
	40	Carbide left after 90 hr.
	60	„ „ „ 110 hr.

decomposed by annealing at 600° C. under the following conditions:

(i) The steel should be in a cold-worked condition
(ii) The subcritical anneal at 600° C. should be carried out in an oxidizing atmosphere.

Both of these conditions have to be satisfied simultaneously to produce rapid graphitization. A comparison of the results for the 3·0% and the 2·3% Si steels shows the effect of increased silicon content in decreasing the time required for complete graphitization of a practically identical carbon content.

The effect of an oxidizing atmosphere in promoting graphitization is similar to what has been reported for plain carbon steels containing small amounts of aluminium. The results of tests on the effect of annealing atmosphere coupled with the effects of sample thickness and type of surface indicate that a diffusion process, in which oxygen is involved, takes place during annealing at 600° C. in a slightly oxidizing atmosphere. The aluminium content of the three steels used in these tests was very low, and it is not

Table IV

EFFECT OF SAMPLE THICKNESS ON TIME REQUIRED FOR COMPLETE GRAPHITIZATION

Sample	Thickness, in.	Result
3·0% Si, 20% cold-reduced	0·060	Completely graphitized in 12 hr.
	0·040	„ „ „ 9 hr.
	0·030	„ „ „ 5½ hr.
2·3% Si, 10% cold-reduced	0·060	„ „ „ 34 hr.
	0·050	„ „ „ 23 hr.
	0·040	„ „ „ 14 hr.
	0·030	„ „ „ 8 hr.

Table V

GRAIN SIZES (A.S.T.M. NUMBERS) OF VARIOUSLY REDUCED TEST PIECES AFTER SUBCRITICAL ANNEAL AT 600° C.

	3·0% Si Sample			
Amount cold-reduced, %	10	20	40	60
A.S.T.M. No.	6·0	6·0	7·5	8·5
	2·3% Si Sample			
Amount cold-reduced, %	10	20	40	60
A.S.T.M. No.	6·5	6·5	8·5	9·5
	1·8% Si Sample			
Amount cold-reduced, %	10	20	40	60
A.S.T.M. No.	7·5	7·5	8·0	9·0

considered that alumina formed by 'internal oxidation' nucleates the graphite. In these silicon steels, silicon must be 'internally oxidized' to silica and it is the dispersions of silica which nucleate the formation of graphite.

Internal oxidation, in the usually accepted sense of the term, cannot take place at 600° C. to the extent involved in these tests because of the exceedingly slow rate of lattice diffusion of oxygen and silicon at this temperature.[11] The oxygen atoms must therefore diffuse along the easier path afforded by the grain boundaries, as suggested by Dennis.[7] The fact that the graphite nodules were almost invariably present at the grain boundaries, which was used by Dennis in support of his grain-boundary diffusion theory, was confirmed in the case of these silicon steels.

There will be present in the silicon steels used for these tests silica particles formed during the molten stage, and, if grain-boundary diffusion of oxygen can occur at 600° C. it should take place at a considerably increased rate at the higher temperatures used for the hot-working of the steels. However, it must be that these silica dispersions already present in the steel are not capable of acting as very effective nuclei for graphitization. It would seem that effective nucleation depends on some critical agglomeration of silicon and oxygen atoms, or the silica particle must be actually in the process of formation.

The fact that increasing above 10% the amount of cold-deformation by rolling resulted in an increase in the time required for complete graphitization is rather surprising. The specimens reduced 10% and 20% did not recrystallize at 600° C., whereas 40% and 60% reduction did produce recrystallization and a smaller grain size than that of the as-hot-rolled specimen (*see* Table V).

The smaller the grain size the longer is the grain-boundary path from the surface to the centre of the specimen, but the number of such paths will be very much greater. The nodule size of the graphite in the samples given 40% and 60% reduction was smaller than in the samples reduced 10% and 20%, but no quantitative measurements were carried out.

Increasing the amount of deformation would also increase the rate of spheroidization of the pearlite. Annealing samples in hydrogen for varying times before annealing in the nitrogen atmosphere produced varying degrees of spheroidization and it was found that the time required in the nitrogen atmosphere for complete graphitization increased as the period of

prior anneal in hydrogen was increased. This suggests that spheroidization decreases the speed of one or more of the three processes of solution, diffusion, and reprecipitation which are involved in graphitization of carbide. The process most likely to be affected is that of solution.

CONCLUSIONS

(1) Decomposition of the carbide phase in low-carbon Si steels cold-reduced 10% by rolling takes place readily on annealing at 600° C. in a slightly oxidizing atmosphere of cylinder nitrogen.

(2) Annealing in hydrogen or *in vacuo* does not produce a similar carbide decomposition.

(3) Increasing the amount of cold-reduction above 10% actually produces an increase in the time required for complete graphitization.

(4) The time required for complete graphitization increases with the thickness of the sample, all other things being equal.

(5) The stability of the carbide phase decreased as the silicon content of the steels increased.

(6) It is considered that nucleation of graphite during the annealing of cold-worked silicon steels in a slightly oxidizing atmosphere is brought about by diffusion of oxygen atoms into the metal during the actual graphitizing anneal. Evidence suggests that this movement of oxygen atoms occurs along the grain boundaries.

Acknowledgments

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References

1. C. R. Austin and M. C. Fetzer: *Trans. Amer. Soc. Metals*, 1945, vol. 35, pp. 485–529.
2. M. A. Hughes and J. G. Cutton: *Ibid.*, 1946, vol. 37, pp. 110–129.
3. C. H. M. Jenkins, G. A. Mellor, and E. A. Jenkinson: *J. Iron Steel Inst.*, 1942, No. I, pp. 51P–86P.
4. J. H. Andrew and H. Lee: *Ibid.*, 1950, vol. 165, pp. 145–184.
5. G. V. Smith, J. A. MacMillan, and E. J. Dulis: *Trans. Amer. Soc. Metals*, 1951, vol. 43, pp. 692–711.
6. E. J. Dulis and G. V. Smith: *Trans. Amer. Soc. Metals*, 1954, vol. 46, pp. 1318–1330.
7. W. E. Dennis: *J. Iron Steel Inst.*, 1952, vol. 171, pp. 59–63.
8. F. Brown and M. F. Hawkes: *Trans. Amer. Found. Soc.*, 1952, vol. 60, pp. 635–639.
9. S. W. Palmer: *Brit. C.I. Res. Assoc., J. Res. Dev.*, 1953, vol. 5, pp. 26–37.
10. J. V. Dawson, L. W. L. Smith, and B. B. Bach: *Ibid.*, 1953, vol. 4, pp. 540–552.
11. E. J. Dulis and G. V. Smith: *J. Iron Steel Inst.*, 1953, vol. 173, p. 52.

Measurement and Influence of Preheat in the Open-Hearth Furnace

By W. P. Cashmore

SYNOPSIS

The variations in preheat within a particular heat of an O.H. furnace are considered, and also trends with time within a campaign. It is shown that an increase of 100° C. in the preheat leads to an increase in working rate of about 0·5 tons/hr. and a reduction in fuel consumption of 2–3 gal./ton.

Comparison of the working rate and fuel consumption as functions of preheat for particular designs of single-uptake and double-uptake furnaces suggests that the former give better results for a particular preheat. However, this advantage is offset to some extent by the increased pick-up of preheat due to the greater surface area of the brickwork in the uptakes in the latter, which results in a higher preheat for a given regenerator capacity. The apparatus and experimental technique used to effect the measurements are discussed. 942

EXPERIMENTAL RESULTS AND DISCUSSION

Introduction

It is one of the inevitable conditions of operation in the open-hearth furnace that high-grade heat has to be rejected through the outgoing port end in the waste gases. Since such heat is expensive, it is highly desirable that as much as possible should be salvaged and should re-enter the furnace in the form of air preheat. Not only does this mean that for a given fuel input the net rate of flow of heat into the furnace is accelerated, but, in addition, the flame temperature rises, which can result in a considerable increase in the difference between flame and bath temperatures. In the absence of a major drop in flame emissivity this would be expected to augment that fraction of the heat in the flame transferred to the bath. It is also possible that the hotter air and keener flame could have a beneficial effect from a metallurgical point of view.

These considerations have long been well known to steelmakers. However, comparatively little work appears to have been done in connection with the

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measurement of air and waste-gas temperatures on the O.H. furnace.

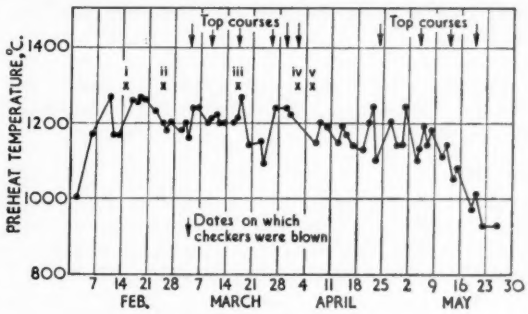
Schack[1] seems to have been the first to measure air and waste-gas temperatures successfully in the O.H. furnace. He showed that the air temperature at the top of the uptake lay in the range 1150–1350° C. The waste-gas temperature at the same point was shown to be just over 1500° C., rather lower than had been generally anticipated. He was also able to show that the waste-gas temperatures drop 200–400° C. in passing through the uptakes and slag pocket, whilst the preheat of the incoming air is increased by about 150° C. between the top of the air checker and the measuring point above stage level. He was therefore apparently the first to prove the importance of the slag pocket and uptakes as regenerative elements. Schack was able to demonstrate from calculation that rather less than 40% of the heat given up to the brickwork by the waste gases could be expected to be used in heating the incoming air, even in the absence of infiltration. The results quoted were obtained on gas-fired furnaces, but they are nevertheless in broad agreement with those based on measurements made at Cardiff on furnaces fired with liquid fuel. Schack's results were obtained using the design of suction pyrometer named after him, in which the annular region between the hood and the sheath is filled with small refractory tubes, which probably have much the same effect as a series of concentric hoods.

Halliday,[2] who carried out a series of measurements at Templeborough with a simple suction pyrometer consisting of a refractory hood concentric with the thermocouple sheath, was able to obtain a relationship between the waste-gas temperature and the subsequent preheat. He was also able to show that variations of temperature across the uptake were very small at points not close to the walls. This is presumably due to the high degree of turbulence obtaining in the uptakes. It has been possible to confirm this, and so there is no reason to suppose that the point at which the measurement is taken is critical, provided that it is not very near the uptake walls.

From the way in which the waste-gas temperature varied with time during a reversal, he deduced that the waste gases gave up considerable heat to the port-end brickwork before entering the uptake. Although no account seems to have been taken of the thermal inertia of the suction pyrometer, there is good reason to suppose that his conclusion is correct.

Marsh[3] at Bethlehem measured preheat on 75 heats in about half as many furnaces at four different shops, using a suction pyrometer having five concentric hoods made of nickel. He was able to relate charge-to-tap time to preheat, and deduced that an increase in preheat of 100° C. would lead to an improvement in working rate of about 16%.* He was able to relate the preheat at the top of the uptake and the temperature of the top of the checkers, and showed that 10% of infiltration resulted in a drop of 30° C. in the difference between these.

It seemed desirable that the work relating to the effect of preheat on working rate should be repeated and extended, using for each correlation results obtained from one furnace only, the design of the furnace being the same throughout the period considered, in the sense that no change should be made which significantly affected the flow patterns in the furnace laboratory.



Dates on which 'sealing' took place
i. South end : stopping holes
ii. North and south ends : stopping holes
iii. and iv. North end : stopping holes

Fig. 1—Variations in preheat during one campaign recorded in north uptake of furnace *E* (refining period)

Under the conditions obtaining at Cardiff, the preheat attains a maximum value during the refining period. This is the nearest approach to the steady state during the entire heat, and is also the time when the effects of variations in fettling and charging times are least. Also, variations between reversal means during the charging period are greater than those when the furnace is refining. Therefore, it was considered that measurements made at this stage of the heat would give the best estimates of the regenerative ability of the furnace as a whole. It was appreciated that these estimates would, of course, still be subject to random fluctuations, caused by such factors as the type of steel being made, slag bulk, etc.

Subsequent examination, however, has indicated that variations between the average preheat during the charging periods of successive heats are not appreciably greater than is the case when the refining period is considered. Presumably this means that the variations within a particular heat are small compared with those between different heats.

Such variations in preheat as have taken place have been due partly to random causes and partly to definite action having been taken, such as spraying the port ends or increasing the checker capacity. Spraying would be expected to decrease the infiltration in addition to insulating the port end. Hence, there will be a tendency for a rise in preheat obtained in this way to be accompanied by a reduction in the actual air flow. However, such Orsat analyses as have been taken give no indication that low preheats are associated with high oxygen contents in the waste gases or *vice versa*. This may be due partly to the fact that the furnaces studied seem to have carried a practically constant amount of metered air during the refining period, and, as will be shown later, higher fuel rates were necessary when the preheat was low. Hence, the presence of infiltrated air would tend to be masked by the consequently increased fuel input rate.

*A fettling time of 40 min. has been assumed to deduce this figure.

It should be emphasized that the purpose of the work was not to obtain in the first instance a precise estimate of the effect of preheat on furnace operation, but rather to determine whether preheat had an appreciable effect, and if so, of roughly what magnitude this was.

Results

The following results were obtained on furnaces *D* and *E*, both of which are of 100 tons capacity and generally tap 100–105 tons. The former has two uptakes having a total of 64 sq. ft. cross-sectional area and a doghouse, and the latter has a single uptake of 48 sq. ft. area. Both charge 50% of hot metal and were fired with liquid fuel only during the period considered.

In Fig. 1, the variation in preheat in the north uptake during one campaign of furnace *E* is shown, the measurements being taken during the refining period. There is a gradual drop in the average for the first 14 weeks of the campaign and then a relatively sharp falling away. A fluctuation of less than 30° C. either way is not likely to represent a significant change. During the campaign, the checkers were blown, and sealing-up took place on the dates indicated. It is difficult as yet to draw any firm conclusions about the value of either procedure, but the general indications are that both are beneficial during the greater part of the campaign, although the value of blowing has diminished towards the end. The design of the checker in question is approximately of the flue or chimney type in the side elevation, but it is pigeonholed in the other elevation, the flue or chimney opening being 6 in. × 6 in.

Figure 2 shows the variation of preheat during one heat of furnace *E*. A pyrometer was inserted in each of the single uptakes of this furnace at points about 3 ft. above stage level. Air-temperature measurements were also made immediately above the checkerwork and in the culverts on the north checker. The diagram gives these results, and also the readings of the total radiation pyrometers sighted on the hottest part of the top course of the checkerwork. All readings represent reversal averages, with the exception of the waste-gas temperatures, which are spot readings.

The air temperature at the top of the uptakes rises about 100° C. from the end of charging to the refining period, the preheat being roughly constant during the latter. The lower preheat during the charging period is presumably due principally to the chilling of the waste gases, caused by charging cold material in the furnace, and the increased infiltration of cold air, caused by the continuous opening and closing of doors. This point has already been observed and commented on by both Halliday and Marsh. Indeed, the latter was able to obtain a correlation between the average air temperature in the period between starting charging and hot-metal addition and that obtaining during the refining period. He also observed that the rise was of the order of 100° C. It appears from his data that the magnitude of the rise is not greatly affected by the preheat level. The data obtained at Cardiff are in agreement with this, save that the average value of the rise is about half that observed by Marsh, and there also appears to be a slight tendency for it to decrease as the preheat increases.

The temperature of the air leaving the top of the checker does not vary greatly through the heat. Thus, the bulk of this increase in preheat from the charging to refining period is apparently obtained during the passage of the air through the slag pockets and the uptakes. It is probably attributable to the fact that the difference between waste-gas and brickwork temperature in these parts is greater during the refining than the charging period. Also, the smaller quantities of air and waste gas passing during the refining period reduce the thermal loading on the brickwork. This factor may also contribute to the increased pick-up of heat. The results are therefore in agreement with those of Schack, who seems to have been the first to emphasize the importance of the regenerative effect of the slag pockets and uptakes.

The single-uptake design has a smaller pick-up of heat from the top of the checker to the top of the uptake during the refining period than the double-uptake design, presumably owing to the greater surface area traversed by the gases, the difference being about 100° C. In the tilting furnaces, which offer an even greater area of brickwork to the air and waste gases, the difference is even more pronounced, the pick-up in temperature being sometimes as great as 200° C. Also, the waste gases do not exceed 1630° C. at any period of the heat. Since it is known that the temperature of the roof at the outgoing end of a furnace at this stage of the heat lies between 1660° and 1680° C., it does not seem possible that the waste-gas

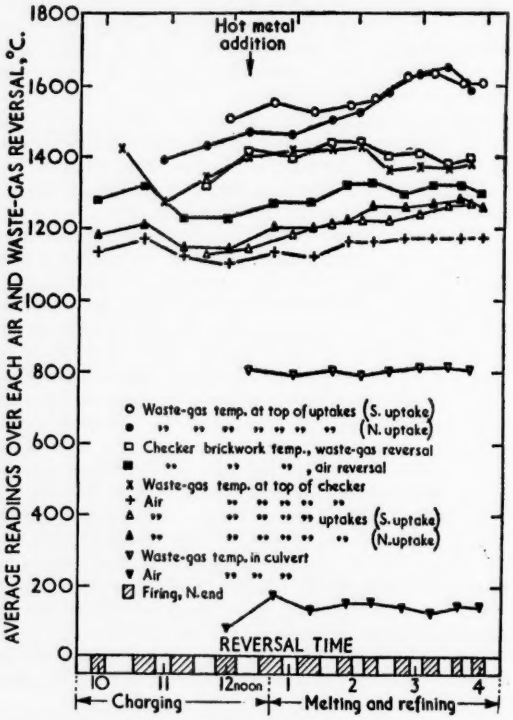


Fig. 2—Variations in preheat during one heat of furnace *E*

temperatures in this region can be less than this. It therefore appears that a reduction in the waste-gas temperature of about 70° C. occurs between the outgoing end of the bath and the top of the uptakes. This point was first made by Halliday from consideration of the variation of the suction-pyrometer reading during the waste-gas cycle, but his reasoning is open to the objection that he seems to have made no allowance for the thermal inertia of the pyrometer which, as indicated elsewhere, is appreciable. Nevertheless, the basis of his reasoning would appear to be correct.

Application of Results

It was desired to determine the effect of preheat on working rate and fuel consumption. For this purpose the two 100-ton fixed furnaces (*D* and *E*) were chosen. It was decided to use weekly averages in the scatter diagrams showing working rate and fuel consumptions as functions of preheat. The preheat considered is that obtaining during the refining period, since, for reasons already discussed, it was considered that this provided the best estimate of the regenerative efficiency of the furnace.

In Figs. 3*a* and *b* the working rate is plotted against preheat for furnaces *D* and *E*, respectively. The best lines have been drawn through these points, based on the well-known method of least squares. Although considerable scatter exists, definite trends are apparent. Statistical analysis gives good reason to suppose that definite relationships exist. The chances are greater than 100 : 1 against the degree of correlation obtained being due to chance causes for both furnaces.

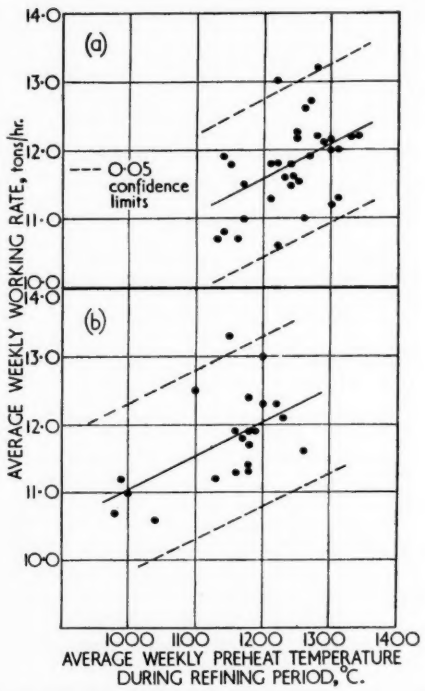


Fig. 3—Relationship between working rate and preheat: (*a*) Furnace *D*, (*b*) furnace *E*

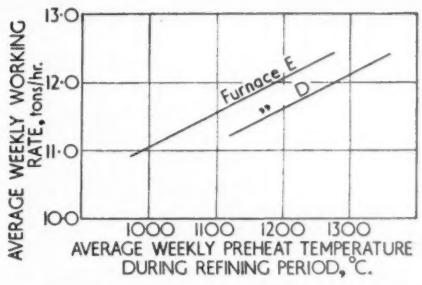


Fig. 4—Comparison of working-rate/preheat curves of furnaces *D* and *E*

In Fig. 4, the regression lines for both furnaces are shown ; the comparison obviously favours furnace *E*. There might be some doubt, however, as to whether the difference means very much, in view of the amount

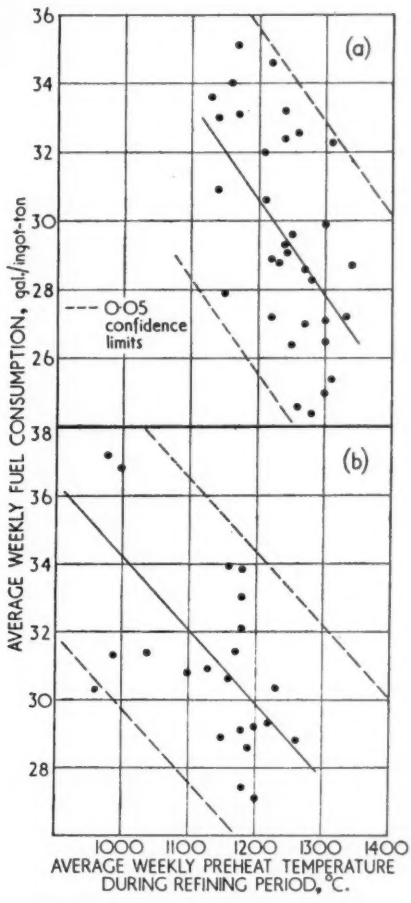


Fig. 5—Relationship between fuel consumption and preheat: (*a*) Furnace *D*, (*b*) furnace *E*

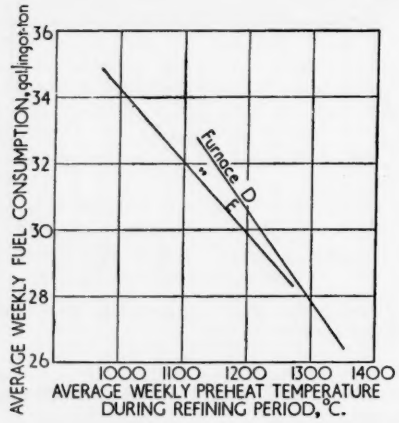


Fig. 6—Comparison of fuel-consumption/preheat curves of furnaces *D* and *E*

of scatter which exists. Again invoking well-known statistical methods, it would appear that the odds against the difference not being real are 100 : 1. This does not mean that the difference is exactly that shown in Fig. 4, but that there is strong evidence that furnace *E* works appreciably faster than furnace *D* for a given preheat.

In Figs. 5*a* and *b*, similar diagrams have been plotted showing the relationship between fuel consumption and preheat. As before, the best straight line through the scatter of points for each diagram has been estimated using the principle of least squares. Again, statistical analysis confirms that the trends are reliable, since the odds against the degree of correlation attained being due to chance are greater than 1000 : 1 against for furnace *D* and greater than 100 : 1 against for furnace *E*.

The two regression lines so obtained are both plotted in Fig. 6 for comparison. The fuel consumptions apparently tend to become identical for both furnaces as the preheat increases, but furnace *E* has a rather lower fuel consumption in the low-preheat range.

The estimates of preheat used in the construction of Figs. 3*b* and 5*b* are in most cases based on readings obtained at one end only. Subsequent work confirms that such an estimate rarely differs from the average for both ends by more than 20° C. This error is obviously negligible when the scatter due to other factors is considered. The estimates of preheat used in the construction of Figs. 3*a* and 5*a*, however, are generally based on the average of the readings in all four uptakes. The decrease in fuel consumption per 100° C. increase in preheat is 2–3 gal./ton.

It should be emphasized that the presence of scatter in these diagrams indicates that a higher preheat will not invariably result in a higher output and lower fuel consumption. If the latter were true, it would mean, of course, that the influence of metallurgical and operational factors other than preheat was negligible, which is obviously not the case. What it does mean, however, is that maintaining a high preheat over a period of time will result on the average in a decrease in fuel consumption and an increase in working rate ; it is, of course, such long-term averages which are of interest to the melting-shop manager.

An example of the way in which other factors can for short periods lead to apparently anomalous results is the effect of the presence of slag which is either foaming or tending to foam. This prevents the bath from picking up much heat from the flame and results in abnormally high waste-gas temperatures. These in turn make the checkers hotter than usual, and so result in an increase in preheat. This increase is, however, not beneficial and is the sign of something wrong with the metallurgy of the process. Such preheat might be termed ' false,' as compared with the ' natural ' preheat which obtains under normal conditions. ' False ' preheat may also be obtained if the fuel is not completely burned in the laboratory of the furnace. Only ' natural ' preheat in the sense defined is considered to be beneficial.

The fuel-consumption/preheat curves in Fig. 6 give an indication of the improvement in the efficiency with which the heat in the fuel can be transferred to the bath as the temperature of the incoming air increases. As a check on this estimate, those heats on furnace *E* were sought out in which the tapping temperature had to be kept constant for about ½ hr. or longer owing to factors such as bath condition, and the fuel rate necessary to maintain tapping heat was noted. Although bath depth, slag bulk, type of steel made, and several other factors will have an effect on this fuel rate, on the average the more efficiently the heat in the fuel is transferred to the bath, the less fuel will need to be carried. With this in mind the average fuel rate necessary to maintain tapping temperature was plotted in Fig. 7 against the average preheat during the refining period, such averages extending over weekly periods. Each point is based on at least six heats. A trend definitely exists, and this is supported by statistical analysis, according to which the chances of the degree of correlation existing being due

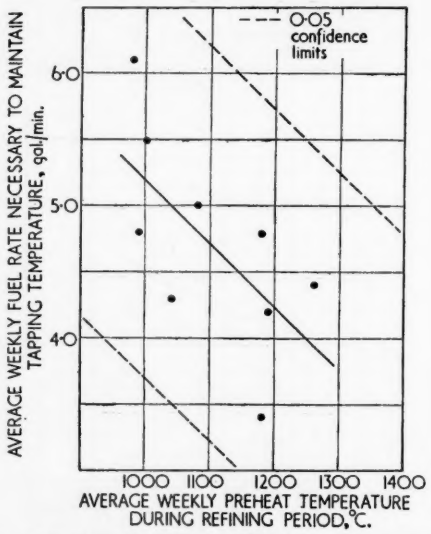

0·05 confidence limits
AVERAGE WEEKLY FUEL RATE NECESSARY TO MAINTAIN TAPPING TEMPERATURE, gal./min.
6·0
5·0
4·0
1000 1100 1200 1300 1400
AVERAGE WEEKLY PREHEAT TEMPERATURE DURING REFINING PERIOD, °C.

Fig. 7—Relationship between fuel rate necessary to maintain tapping temperature and preheat (furnace *E*)

to random causes are 20 : 1 against. Again, the best straight line has been drawn in.

According to this diagram increasing the preheat from 1000° to 1200° C. results in an increase of 20% in the efficiency with which the heat in the fuel is transferred to the bath, whilst the fuel-consumption/preheat graph (Fig. 6) gives 14% as the corresponding figure, which, in view of the scatter obtaining in both diagrams, would not appear to be significantly different. Thus, the two different approaches give similar estimates.

The increase in preheat is not the result of higher oil rates being carried during the charging and melting periods. In reality, when the preheat is high, less fuel tends to be carried during all periods. This is not deliberate ; it probably indicates that, during the charging period, the flame is warming up the scrap to the desired extent as fast as the latter can be supplied, whilst the roof temperature will possibly be the biggest factor which will influence the furnaceman in deciding what fuel rate to carry during the melting and refining periods. A careful analysis of charging rates, percentage of scrap, and tons of steel tapped per heat gives no reason for supposing that the observed trends are due to these factors.

Although one design of single-uptake furnace appears to be superior to a particular design of double-uptake furnace with a doghouse under the conditions obtaining in Cardiff melting shop, this should not be taken to indicate a general superiority of the single-uptake over the other design. A great deal more work would obviously have to be done before this very important question could be answered.

There is no reason to suppose that higher preheats necessarily lead to increased refractory wear. In fact, the tendency is for the lower fuel rates associated with high preheats, together with the more efficient heat transfer, to reduce the waste-gas temperatures. However, the fact that higher preheat makes the furnace keener does mean that it may be easier for the melter to catch the roof, although this is probably a characteristic of all keen furnaces.

Conclusions

(1) Relationships between air preheat and working rate have been obtained for two 100-ton fixed furnaces, one having double uptakes and a doghouse and the other a single uptake.

(2) For both furnaces, a 100° C. increase in preheat increased the working rate by 0·5 tons/hr.

(3) The single-uptake furnace worked faster than the twin-uptake furnace by about 0·4 tons/hr. for all values of the preheat. It is considered that the difference is significant.

(4) Relationships have been obtained between preheat and fuel consumption for both furnaces.

(5) Increasing the preheat by 100° C. decreases the fuel consumption of the double-uptake furnace by 2·8 gal./ton, and leads to an improvement of 2·2 gal./ton for the single-uptake furnace.

(6) Both furnaces tend to have the same fuel consumptions for values of the preheat of about 1300° C., but for low preheats the single-uptake design appears to have the lower fuel consumption, there being a difference of 1·3 gal./ton at 1100° C. in its favour.

(7) The double-uptake furnace tends to have a preheat of 50–100° C. more at the corresponding period of the campaign than the single-uptake furnace. The difference is largely due to the increased pick-up of preheat between the top of the checker and the top of the uptake, due probably to the significantly greater surface area of brickwork exposed to the air and waste gases in the former design.*

(8) The amount of fuel necessary to maintain tapping temperature is related to the preheat. As the latter increases, the necessary fuel rate decreases.

(9) The percentage reduction in the fuel rate necessary to hold tapping temperature, for a given increase in preheat, is approximately the same as the percentage reduction in fuel consumption under the same conditions. This is to be expected, since both quantities should be inversely proportional to the efficiency with which the heat in the fuel is transferred to the bath.

(10) The improvement in combustion efficiency accompanying an increase in preheat is attributed largely to the higher flame temperature. Since the difference between the latter and the bath temperature in the melting and refining periods is not great, a small rise in the flame temperature leads to a considerable increase in this difference, which might be expected to have a beneficial effect on the heat transfer from the flame to the bath.

It is, however, unfortunate that it has not been possible to assess definitely the importance of the various factors affecting the degree of preheat obtained. However, such routine Orsat analyses as have been taken during the periods considered during this work did not indicate that high preheats give low or that low preheats give high oxygen contents in the waste gases, even though the amount of metered air carried has been the same. However, it is very possible that a compensating effect exists in this connection. Since the oxygen contents of the waste gases do not seem to have varied a great deal over this period, being consistently about 2%, there seems good reason, therefore, to suppose that the improvements associated with high preheats are to be attributed to higher flame temperatures.

(11) Increased flame temperature is also the probable cause of the rise in working rate resulting from greater preheat, but the possibility of the latter having metallurgical advantages is not precluded.

(12) Figure 2 shows that the temperature of the waste gas in the culverts leading from the checkers is 700–800° C., whilst that of the incoming air at the same point is very much lower. This therefore represents a very poor recovery ; it is, of course, true that these gases are used to operate waste-heat boilers, but it would nevertheless seem to be desirable to extract more of this heat if possible, even at the expense of the resulting increase in the maximum temperature of the checker brickwork.

(13) It has not been possible to prove that length of reversal has any great effect on the average preheat. This is broadly in line with the findings of Kistner[4] and also of Finlayson and Taylor.[5]

*Conclusions 3 and 5–7 should not be taken to indicate a general superiority of single-uptake furnaces, but only that a particular single-uptake furnace appears to be better than a particular double-uptake design.

Although the average preheat does not seem to be affected by length of reversal, since the average rate of drop of the incoming air temperature is about 8° C./min., there is a distinct advantage in working with shorter reversals. If the furnace is driven hard, unless the fuel is being continuously adjusted during a long reversal, there is a danger of catching the roof just after reversing, particularly during the refining period. This has been confirmed in practice. Hence, reversal length must not be too long, otherwise the range in preheat will be excessive, nor must it be too short, or the fuel will be off the furnace for too great a proportion of the time.

During charging, the effect of the higher preheat obtained at the start of a long reversal might more than compensate for the lower preheat in the second half of the reversal. However, this would be true only if the roof were relatively cold. The longer reversal periods carried during charging generally appear to be due to considerations related to the charging and cutting-down of the scrap rather than to preheat.

(14) The factors affecting the preheat attained on a furnace seem to be :

(i) Overall regenerative efficiency
(ii) Surface heat losses
(iii) Infiltration.

It has not yet been possible to determine the relative importance of these factors, but it is hoped that this will be effected in the near future. However, it seems that whatever the cause of the variations in preheat, a high preheat is definitely desirable, and there is no reason to suppose that an optimum value has yet been reached.

EXPERIMENTAL METHODS

Apparatus

When the measurement of preheat (and also, to a lesser extent, of waste-gas temperature) was started, a conventional design of suction pyrometer was used in which the pyrometer head was fixed into the water jacket. Under these conditions, running a test imposed a great strain on all concerned. To start with, the water supply at Cardiff is low-pressure and not particularly clean, and so the water jackets had to be comparatively large. Thus, inserting a suction pyrometer into an uptake required a considerable effort, owing to the weight involved. Connecting the flexible hose and the compensating lead also took an appreciable time. In addition, in the event of a pryometer giving a doubtful reading, little or nothing could be done about it, owing to the considerable length of time involved in removing the pyrometer, replacing the refractory head, warming the latter up, and replacing the pyrometer in the uptake. There was also the danger of breaking the refractory head on inserting it through the hole in the uptake wall and the difficulty involved in warming up a refractory head at a definite scheduled rate before insertion. The latter point has a considerable bearing on the effective life of the pyrometer.

With these points in mind, the design of pyrometer shown in Fig. 8 was evolved. No great claims are made for this, but in its design considerable thought

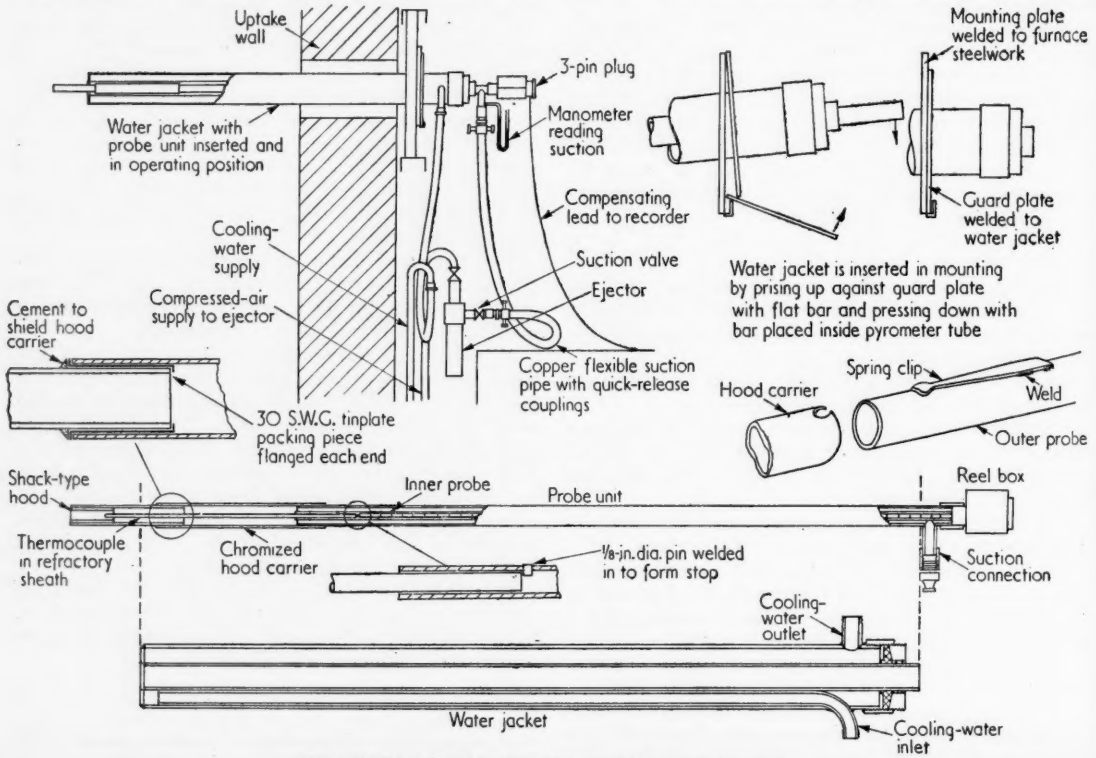

Uptake wall
3-pin plug
Mounting plate welded to furnace steelwork
Water jacket with probe unit inserted and in operating position
Manometer reading suction
Compensating lead to recorder
Guard plate welded to water jacket
Cooling-water supply
Suction valve
Ejector
Water jacket is inserted in mounting by prising up against guard plate with flat bar and pressing down with bar placed inside pyrometer tube
Compressed-air supply to ejector
Cement to shield hood carrier
Copper flexible suction pipe with quick-release couplings
Spring clip
Hood carrier
Weld
Outer probe
30 S.W.G. tinplate packing piece flanged each end
Shack-type hood
Inner probe
Probe unit
Reel box
Thermocouple in refractory sheath
Chromized hood carrier
⅛-in. dia. pin welded in to form stop
Suction connection
Cooling-water outlet
Water jacket
Cooling-water inlet

Fig. 8—Design of pyrometer used for experiments

has been given to the elimination of the difficulties mentioned, in addition, of course, to ensuring the vital requirement that the actual reading of the pyrometer itself should be reliable. As much simplification as possible has also been introduced to make the equipment cheap. The gland at the end of the water jacket, for instance, is rather unorthodox, but will stand a pressure of 150 lb./sq. in. without leaking; it has never given any trouble during long periods of service under arduous conditions, and represents a very real financial saving in comparison with the orthodox gland. It should be borne in mind that the design has been evolved from conventional origins. Experience has indicated what simplifications can be made without any detrimental effect.

An unusual feature is the separation of the actual suction pyrometer and the water jacket. This enables a pyrometer giving a doubtful reading to be replaced very quickly, and also has advantages in bringing the refractory hood up to the working temperature. Several pyrometers can be prepared under laboratory conditions and brought to the furnace as required. They are light enough for two to be carried quite long distances by one person with little effort, and under exceptional conditions four can be carried.

The water jacket may either be built into the uptake and left there or, alternatively, can be inserted and removed for each test. Provided that the type of mounting shown in Fig. 8 is used, the latter procedure does not call for much effort and can be entrusted to unskilled labour without prejudicing the possibility of running a test.

The suction pyrometer itself is built almost entirely of standard steam pipe and pipe fittings, with the exception of the hood carrier, which is a piece of drawn tube 1½ in. outside dia. × 14 S.W.G. wall thickness. The life of the hood carrier may be considerably extended by chromizing, which reduces the scaling and oxidation during the test. Some cement is used to shield the front end of the hood carrier. The refractory hood is fixed into the hood carrier by means of the small tinplate clip also shown in Fig. 8.

In making up a pyrometer, the hood is first completed and fixed in the hood carrier. The latter is then fixed on to the pyrometer. Originally, a screw thread was used to join the two, but it was found that there was a slight tendency for the thermocouple to be twisted while the connection was being effected. There are ways of minimizing this possibility, but it was considered that the best course was to replace the screw thread with the clip, thus removing the cause of the trouble.

The refractory sheaths containing the thermocouple are rather long, so as to prevent the inner probe from being burned away. They might possibly be shortened without adverse effect.

The actual design of hood used is of the Schack type. A ring of mullite tubes is fixed to the inside of the hood by means of recrystallized alumina cement mixed with a small percentage of ball clay to improve its adhesive properties.

Several papers have been written advocating the use of multiple hoods. For instance, Marsh[3] used a design of pyrometer which utilized five concentric nickel hoods. In Fig. 5 of his paper he shows that when his suction pyrometer was reading 1100° C., the walls of the uptake being at about 1365° C., the reading given by a bare couple was 1310° C. A rough measure of the accuracy of a suction pyrometer is given by the ratio

$$\frac{T_S - T_O}{T_B - T_O}$$

where T_S = Temperature recorded by suction pyrometer
T_O = Uptake wall temperature read by optical pyrometer
T_B = Reading of bare thermocouple in air stream.

It was possible to carry out a similar experiment in connection with the present design of pyrometer such that the suction pyrometer gave a slightly lower reading than that used by Marsh ; the readings of the optical pyrometer and the thermocouple, however, were very nearly the same. There is apparently no reason to suppose that there is any significant difference in the accuracies of the two designs and, in view of the much greater simplicity and cheapness of the modified Schack hood, the latter is to be preferred.

It is thus impossible to make any claims about the absolute accuracy of the pyrometer ; however, there seems to be no reason to doubt that its accuracy is less than that of any other design in use. However, when all factors are allowed for, its overall accuracy is probably about 30° C. Since, as shown later, there is no reason to consider that fluctuations in the day-to-day readings of less than 50° C. are significant, this is acceptable. This accuracy relates to lower preheats ; as the air temperature increases, the accuracy will also increase, since the difference between the air and brickwork temperatures will decrease.

However, in view of the experimental procedure adopted, it seems very probable that the results are at least reproducible. This is substantiated by the fact that readings obtained on furnaces over considerable periods vary by less than 10° C. from day to day.

The refractory sheath should be of good-quality mullite. The hood should be thermal mullite, or thermal alumina if an extended test is required. The insulator tubes should also be of mullite. When used for measuring preheat at the top of an uptake in a fixed furnace of 100–200 tons capacity the mullite may be expected to last 2–4 hr., whereas the alumina would last about 5 hr. and possibly even longer. This relates to furnaces with hot-metal practice using about 50% of hot metal. There is evidence that much extended lives can be obtained under cold-metal practice. Furnace design is also a big factor, since the refractories will last two or three times as long in the Cardiff tilting furnaces, presumably because the port end is of such a shape that a greater proportion of the slag is deposited by the waste gases before reaching the pyrometer.

Suction is provided by an ejector, connected to the back end of the pyrometer by a piece of copper flexible tubing with quick-release connectors at each end. There is a valve between the ejector and the pyrometer which should be closed when the ejector is not working, since it is possible for air to be drawn back through the pyrometer into the uptake under certain

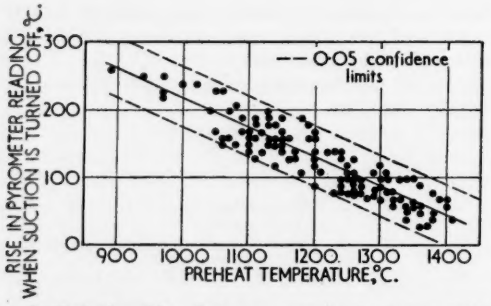


Fig. 9—Relationship between preheat temperature recorded by pyrometer with suction on and rise in temperature when suction is turned off

conditions. It is, of course, preferable to have an ejector attached directly to the back end of the pyrometer if possible ; this leads to a considerable reduction in the quantities of compressed air required.

All electrical connections are made with 3-pin plugs or post-office jacks, to avoid poor contacts and wrong polarity. This also effects an appreciable saving of time at the beginning and end of the test when compared with the conventional terminal connections, particularly if several pyrometers are in use at once.

It is desirable that the results should be recorded on a high-speed potentiometric recorder so that the behaviour of the pyrometer may be kept continuously under review. If this is not possible, the next best thing is probably to use a millivoltmeter of high internal resistance and to plot the results on a graph (*e.g.*, every minute). The millivoltmeter has an advantage over an ordinary laboratory-type potentiometer in that it gives a continuous indication. However, a correction may have to be applied for the resistance of the compensating lead and thermocouple. The essential point, however, is that the results should be plotted on a graph as soon as they are obtained, since this enables faults to be detected more easily than would be the case if the results were recorded as a column of figures.

Experimental Technique

After the apparatus has been assembled, the pyrometer is inserted half-way into the water jacket. By slowly opening the valve controlling the supply of compressed air to the ejector, the temperature recorded by the pyrometer is gradually increased until it is in excess of 1000° C. It is best to do this during a waste-gas reversal and to spend the entire reversal in bringing the pyrometer up to temperature. This results in a heating rate of about 100° C./min. It has been found that such a heating schedule minimizes thermal shock. Strictly speaking, the higher-quality refractories should be warmed up more slowly, but this heating rate has been found to be sufficiently low to deal with all qualities.

After the furnace has reversed, the pyrometer is fully inserted into the incoming air stream and the suction is adjusted to a predetermined value as read by the mercury manometer at the back end of the pyrometer. This value of the suction, known as the ' normal,' is one which past experience has shown to give satisfactory accuracy, judged by the way in which certain conditions (specified below) are fulfilled. In general a reading of 2 in. of Hg is adequate.

It is desirable that the effect of turning the suction off (and also of doubling it) should be determined during each reversal. The rise in reading when the suction is turned off is a function of the preheat. This is clearly shown in Fig. 9. These results were obtained on furnaces *D* and *E* at Cardiff, but they are representative of those obtained from other furnaces, both at Cardiff and elsewhere. The evidence to date suggests that this rise is characteristic of the instrument rather than of the type of furnace, provided that the pyrometer is inserted in the uptake at or above stage level. One of the first signs of a faulty hood is a reduction in this rise, due to an increase in apparent preheat. Doubling the suction should not produce a drop in reading of more than 10° C. If a greater change results, it is generally a sign that the hood is partially blocked with slag. A metering nozzle in the suction line is of great assistance in such

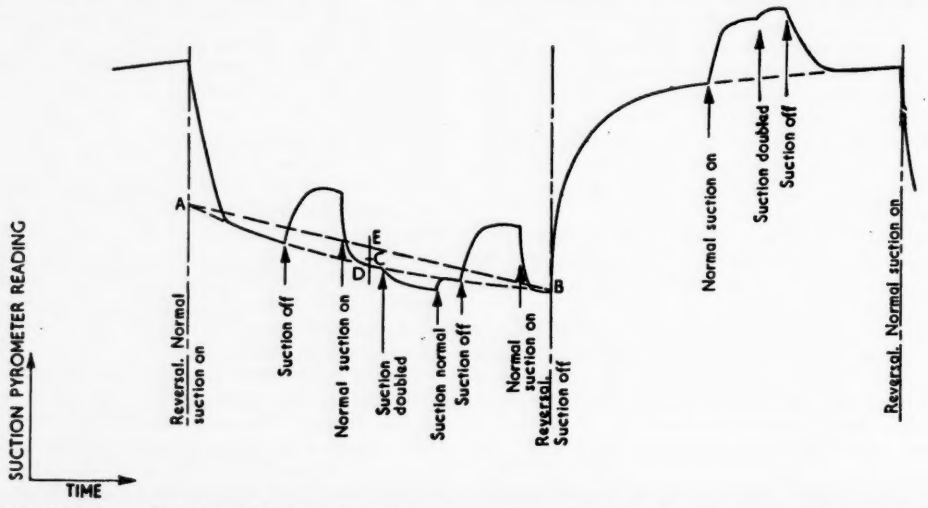


Fig. 10—Diagram showing variation of suction-pyrometer reading during air and waste-gas periods

cases, since it enables a determination of the flow rate to be made. Provided that the latter is greater than 1400 standard cu. ft./hr. and the pyrometer responds satisfactorily to the other checks, the reading may be considered to be reliable.

During the waste-gas cycle, the ejector air-supply is normally turned off and the suction valve is closed, unless readings of waste-gas temperatures are required. When the preheat is high, the effect of turning the suction off during the air cycle is small. In such cases, applying normal suction during the waste-gas cycle will usually result in a rise in pyrometer reading of about 100° C., provided that the hood is still in good condition. This provides an additional check.

Figure 10 shows diagrammatically the way in which the reading will vary during both air and waste-gas reversals when the experimental technique described is used. The drop in reading for a short time after reversal is attributed to the thermal inertia of the instrument. An estimate of the latter may be obtained when the pyrometer is just inserted into the furnace if its temperature is originally less than that of the air. The pyrometer reading reaches a maximum about 1 min. after insertion, and the point of inflection in the temperature/time relationship will occur about 1 min. later. Thereafter, the pyrometer will read the air temperature. It therefore appears that if a sudden jump of 200–300° C. were to take place in the temperature of the air during a test, the pyrometer would read within 10° C. of the air temperature in less than 1 min. and would be reading the actual temperature well within 3 min. The rate of change of the reading when the suction has been put on shortly after reversal gives a very good indication of the condition of the pyrometer. A sluggish response usually indicates that the pyrometer is not working properly.

If, when the suction is doubled during an air reversal, the pyrometer reading drops more than 10° C., the hood is probably partially blocked with slag. Applying the maximum possible suction in a series of bursts will sometimes clear the blockage ; otherwise the pyrometer must be replaced. With the design described in this paper, this change may be effected very quickly, so that no readings need be lost.

If, on the other hand, doubling the suction results in a rise in reading, it should be checked first that the pyrometer is fully inserted. If it is, the fault is generally due to a contact between the two thermocouple wires well back from the hot junction. Moving the reel box will sometimes cure this fault ; otherwise the pyrometer must be replaced.

Pulling out the pyrometer 1 in. in the fixed water jacket when normal suction is applied should give no change in reading. If it does, it shows that the water jacket is having an effect upon the reading. This should not happen if the pyrometer head is properly made up. Such a check is not, of course, possible with the conventional suction pyrometer.

Another fault which occasionally develops is that a slag build-up establishes thermal contact between the sheath and the surrounding mullite tubes. This results in an apparent increase in preheat, without appreciably reducing the effect of closing the suction valve. There is no obvious remedy for this particular fault ; however, it can be almost entirely eliminated by careful attention to the concentricity of the sheath relative to the hood. This emphasizes the importance of the annular space between the sheath and the hood.

In the work described in the first section the average preheat during a reversal was required. The method of estimating this is as follows. Referring to Fig. 10, vertical lines are drawn at the times corresponding to reversal. The rate of drop of the instrument reading for a short time after reversal is attributed to its thermal inertia. To correct for this, the air-temperature/time graph is extrapolated back in the manner indicated. The 'knee' in the curve where the instrument attains the air temperature is readily detectable after a little practice. Some objection has been made to this method, on the grounds that for a short time after reversal the air temperature does in fact drop in the way indicated by the pyrometer reading. Using a design of suction pyrometer with negligible thermal inertia, it has been impossible to detect any such rapid drop for times within as little as 15 sec. of reversal, and hence it is considered that this procedure is justified.

A simple and quick means of estimating the average air temperature during a reversal is as follows. Curve AB in Fig. 10 is so close to straight line AB that the difference between them may be taken as being parabolic. Assuming this, the average air temperature during a reversal is given by point C, where C lies in a vertical line intersecting curve AB at D and straight line AB at E, such that $AE=EB$. If $DC=DE/3$, it is not difficult to show that C represents the time average of the temperature during a reversal.

Since only spot readings are usually taken in the waste-gas cycle, no such technique is required in this connection.

Acknowledgments

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References

1. A. SCHACK : *Arch. Eisenhüttenwesen*, 1929–1930, vol. 3, pp. 7–11.
2. I. M. D. HALLIDAY : " Influence of Port Design on Open-Hearth Flames," Spec. Rep. No. 37, pp. 48–67 : 1946, London, The Iron and Steel Institute.
3. J. S. MARSH : *Yearbook Amer. Iron Steel Inst.*, 1951, pp. 185–207.
4. H. KISTNER : *Arch. Eisenhüttenwesen*, 1929–1930, vol. 3, pp. 751–768.
5. T. C. FINLAYSON and A. TAYLOR : *J. Inst. Fuel*, 1946, vol. 19, Feb., pp. 82–98.

Radioactive Measurement of Valve Leakage, Infiltration, and Blowout in Open-Hearth Furnaces

By E. B. Bell, B.Sc.(Hons.), and D. Thomas, M.A.

SYNOPSIS

A pulse of radon is introduced at the air intake of an O.H. furnace and consecutive gas samples are taken from the waste-gas culvert after the reversing valve. The samples are quantitatively assessed for radon concentration. Any leakage over the valve is detected in the first few samples and the radon completing the normal furnace circuit is detected in the later samples. The quantity of radon passing the sampling point is determined and the loss (blow-out) is calculated. Infiltration is measured by the dilution of the radon in the gas stream. 958

After measurement of the air flow at the intake, the quantity of air supplied to the furnace chamber is governed by

(i) Air infiltration into (and under certain conditions blowout from) the checkers and uptakes
(ii) Direct leakage of air to the waste gas across the reversing valve.

Pitot-tube surveys[1] have permitted measurement of input volume and infiltration when suitable sites for the surveys have been available, but the numerous bends in the vicinity of reversing valves, together with the small leakage anticipated with modern valves, renders this method unsuitable for valve-leakage measurements. In addition, a method of measuring infiltration independently of the furnace construction at the point chosen was desired.

The use of concentration measurements of a gaseous component for determining gas volumes is a standard method in plant work, the most common measurement being the determination of waste-gas volumes by CO_2 or O_2 determinations. It is still possible when the ingoing air system is being investigated to use a gaseous tracer such as CO_2 or O_2, but the extremely large volumes which would have to be added to give a concentration that could be determined with reasonable accuracy by chemical or physical methods of gas analysis make the method barely practicable. The use of radon for flow measurement had already been indicated[2] and, because of the ease with which small amounts of radioactivity could be detected, this tracer technique was developed for quantitative measurements.

THEORETICAL CONSIDERATIONS

Infiltration and Blowout

Consider a system in which there is a known gas flow of V_1 cu.ft. per unit time initially, to which is added an unknown quantity V_2 cu. ft. per unit time (V_1 and V_2 may be dissimilar gases), and from which an unknown quantity V_3 cu. ft. per unit time is lost (Fig. 1*a*). Such a system may represent the junction and division of pipes or ducts, but, for the present purpose, V_2 and V_3 will represent infiltration and blowout, respectively, as known on O.H. furnaces.

If a known amount of radon (R_1) is introduced as a pulse into V_1 prior to A, so that the tracer is thoroughly mixed with V_1, consecutive samples are taken from the stream at A during passage of the radon, and the radon concentration in the samples is assessed to give a histogram of the type shown in Fig. 3, it can be shown[3] that

$$\text{Amount of Rn passing } A = kV_1I_A \quad \ldots\ldots\ldots\ldots (1)$$

where k is a constant depending on the sampling and counting system and I_A equals the area under the curve. If in a similar way samples are taken at B to give an area I_B, from equation (1)

$$kV_1I_A = k(V_1 + V_2)I_B \quad \ldots\ldots\ldots\ldots (2)$$

since the total amounts of radon passing A and B are equal. The infiltration can therefore be found by sampling before and after the section allowing infiltration, and applying equation (2).

In the blowout section BC, however, the concentration of the radon at B and C is the same, even though the amounts passing the two points are different; *i.e.*, I_B will equal I_C and equation (2) cannot be applied.

To determine V_3 it is necessary to introduce a second pulse of radon after the point of blowout (*e.g.*, D) and to take samples at C. If the amount of radon injected at D is R_2 units, and the area resulting from the samples taken at C is I_C from the first pulse and $I_{C'}$ from the second, it can be shown* that

$$\frac{V_3}{V_1 + V_2 - V_3} = \frac{R_1 - \dfrac{I_C}{I_{C'}}R_2}{\dfrac{I_C}{I_{C'}}R_2} \quad \ldots\ldots\ldots (3)$$

and the blowout volume V_3 can be determined.

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* The simple calculation has not been included because of space considerations; details may be obtained on application to the authors or B.I.S.R.A.

In addition, volumes V_1 and $(V_1 + V_2)$ may be found directly from areas I_A and I_B using the first pulse, and volume $(V_1 + V_2 - V_3)$ from $I_{C'}$ at point C using the second seed released at D, by applying the method involving a standard radon source[3] and the equation

$$\text{Flow} = \frac{X}{I} \times \frac{R}{t} \times K \text{ cu. ft. per unit time,}$$

where X = Count from standard source
R = Activity of radon released in gas stream
t = Unit sampling time (*e.g.*, 10 sec.)
K = A factor determined by the sampling system and unit conversions.

This method therefore enables a system in which V_1 is unknown to be investigated, and, should the whole system not require investigation, allows individual volumes to be measured with a reduction in the amount of radon used; *e.g.*, the flow past C may be directly measured using one seed released at D.

If blowout occurs before infiltration, as in Fig. 1*b*, introducing radon (R_1 units) into V_1 and taking samples at A, B, and C, to give I_A, I_B, and I_C,

$$I_A(V_1 - V_3) = I_C(V_1 + V_2 - V_3) \quad \ldots\ldots\ldots\ldots(4)$$

If a second pulse of radon (R_2 units) is released at D_1 or D_2 to give $I_{C'}$ at C,

$$\frac{V_3}{V_1 - V_3} = \frac{R_1 - \frac{I_C}{I_{C'}} R_2}{\frac{I_C}{I_{C'}} R_2} \quad \ldots\ldots\ldots\ldots(5)$$

so that V_3 is determined from equation (5), and substitution in equation (4) provides the infiltration V_2.

Measurements from the first pulse also enable V_1, and from the second pulse (if released at D_1), $V_1 - V_3$ and $V_1 + V_2 - V_3$ to be calculated by the standard radon-source method.

Valve Leakage

With radon (amount R_1) released at A in Fig. 2, and samples taken at B and C, curves similar to those in Fig. 3*a* and *b* are obtained, where I_L, I_R, and I_B represent the radon concentration passing C as a result of direct leakage, that passing C after traversing

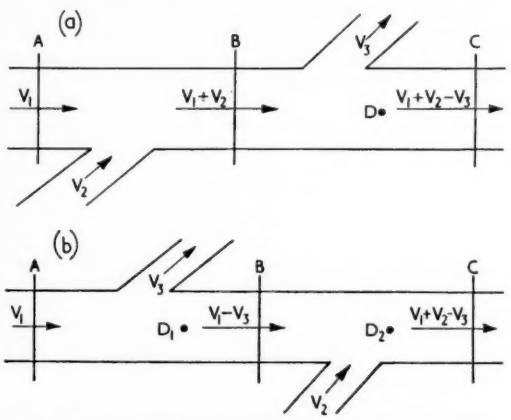

Fig. 1—Schematic system showing (*a*) infiltration before blowout, and (*b*) blowout before infiltration

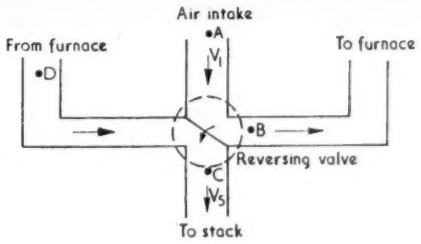

Fig. 2—Schematic arrangement of a reversing valve

the full circuit *via* the hearth, and that in V_1, respectively.

The amount of radon in the leak is kI_BV_L

$$= kI_LV_5,$$

so that

$$\frac{\text{Leakage volume}}{\text{Waste-gas volume}} = \frac{V_L}{V_5} = \frac{I_L}{I_B} \quad \ldots\ldots\ldots\ldots(6)$$

Normally, some loss occurs through blowout, and therefore

$$\text{Total amount of radon} = R_1 = kI_LV_5 + kI_RV_5 + kI_3V_3$$

where I_3 represents the radon concentration* in the blowout V_3.

The absolute values of V_5, V_3, and I_3 are unknown and, to determine the amount of radon passing C, a second seed of value R_2 units is broken at D (*i.e.*, after the blowout section) in the waste-gas system; samples are taken at C to give I_C (Fig. 3*c*). Then the leak as a percentage of the input volume is

$$\frac{I_L}{I_C} \times \frac{R_2}{R_1} \times 100\,\% \quad \ldots\ldots\ldots\ldots(7)$$

and

$$\frac{\text{Input volume}}{\text{Waste-gas volume}} = \frac{V_1}{V_5} = \frac{I_C}{I_B} \times \frac{R_1}{R_2} \quad \ldots\ldots\ldots\ldots(8)$$

The waste-gas volume V_5 is therefore determined.

In addition, it is possible to calculate within limits the total infiltration and blowout rates between the air inlet and point C in the waste-gas culvert. As previously stated, the concentration of radon in the gases escaping from the system is unknown, but it must have a value between I_B and I_R, the concentrations in the gases entering and leaving the furnace system. It can be shown that the blowout volume lies between the limits

$$V_1\left[1 - \left(\frac{I_R + I_L}{I_C}\right)\frac{R_2}{R_1}\right] \quad \ldots\ldots\ldots\ldots(9)$$

and

$$V_5\left[\left(\frac{I_C}{I_R + I_L}\right)\frac{R_1}{R_2} - 1\right] \quad \ldots\ldots\ldots\ldots(10)$$

Since the total infiltration = $V_5 - V_1 + V_3 +$ decrease in volume with combustion (no account is taken of the moisture content of the gases, and so there is a decrease on combustion), the volume infiltration lies between the limits given by

* Blowout will not necessarily occur at constant concentration, so that

where $kI_3V_3 = k\Sigma I_aV_a + I_bV_b + I_cV_c + \ldots$
$V_3 = V_a + V_b + V_c + \ldots$

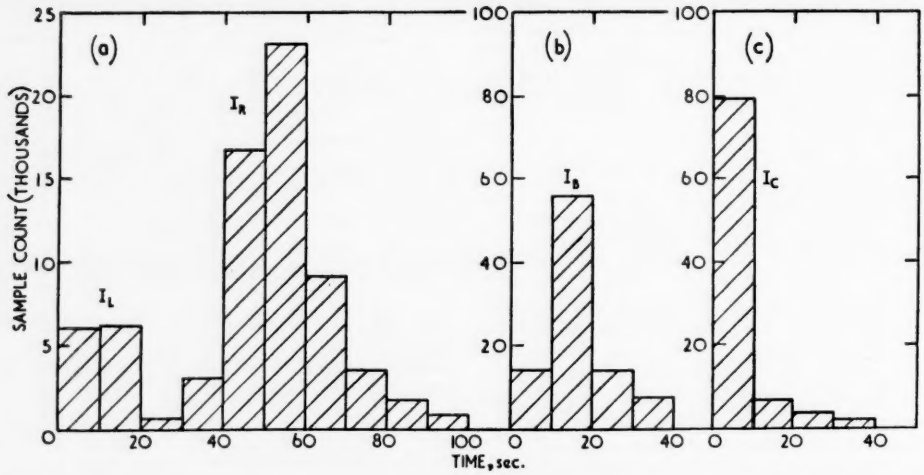

Fig. 3—Activity curves for samples taken from (*a*) waste-gas flue (point *C*), (*b*) air system (point *B*), (*c*) waste-gas flue (point *C*) with radon released in the same system (point *D*)

$$V_s - V_1 + V_1\left[1 - \left(\frac{I_R + I_L}{I_C}\right)\frac{R_2}{R_1}\right] + \begin{matrix}\text{decrease in}\\ \text{volume with}\\ \text{combustion}\end{matrix} \quad \ldots(11)$$

and

$$V_s - V_1 + V_s\left[\left(\frac{I_C}{I_R + I_L}\right)\frac{R_1}{R_2} - 1\right] + \begin{matrix}\text{decrease in}\\ \text{volume with}\\ \text{combustion}\end{matrix} \quad \ldots(12)$$

Obviously, the blowout and infiltration volumes can be determined with greater accuracy if the furnace system is divided into sections and measurements are taken as outlined in the previous section.

If the method using a standard radon source is incorporated, the waste-gas volume V_s may be determined directly from the second pulse, using samples taken at C and the input volume from samples at B, provided that conditions are such that the concentration at B is equal to the concentration in the air supplied to the reversing valve. These concentrations will differ if it is possible for air to infiltrate into the system at or near to the reversing valve and, in this case, the volume passing at point B can be calculated only if the amount of radon leakage across the valve is known and allowed for in the calculation.

APPLICATION OF TECHNIQUE TO DETERMINE VALVE LEAKAGE AND INFILTRATION

The methods of releasing radon, collecting samples, and counting to determine the quantity of radon passing any point are described by Voice, Bell, and Gledhill.[3]

Valve Leakage

The first seed was broken at the air intake and consecutive samples were taken simultaneously from the ingoing air culvert (point *B*) and the waste-gas culvert (point *C*). As soon as sufficient samples had been taken to ensure that all the radon had passed the sampling points,* a second seed was broken in the waste-gas system before the valve (point *D*), and samples were taken from the waste-gas culvert. The radon concentration in each sample was then determined and curves were drawn of the activity against time for each point.

For accurate measurements with this technique, it was essential that the radon was thoroughly mixed in the gas stream at all sampling points, and samples were taken initially at two depths at each point to check this mixing.

Mixing of the Radon

The degree of mixing depends on

(i) Proximity of sampling point to release point
(ii) Bends and obstructions between release point and sampling point.

It was found that with radon released at the air intake, the mixing due to the fan and the subsequent bends in the air system resulted in uniform distribution of the radon at the sampling point in the ingoing air culvert. In the waste-gas system, however, mixing was very much dependent on the type of valve.

Effect of Infiltration at Sampling Point—To prevent stratification effects, it was found essential to seal the point of entry of the sampling pipe to prevent leakage of air into the furnace system, and also to eliminate as far as possible infiltration before the sampling point, particularly when this was in the waste-gas culvert and measurements were being taken on a straight-through valve.

Butterfly Valve—The 90° and 360° bends inherent in this design caused good mixing of both the radon leaking over the valve into the waste gas and the radon released in the downtake system, even when this second seed was broken in the culvert between the checker and the valve.

EXPERIMENTAL RESULTS

Butterfly Reversing Valve

A typical set of results obtained on a 90-ton oil-fired O.H. furnace with a butterfly reversing valve is shown in Figs. 3*a–c*.

* The period of sampling varied according to the position of the sampling point and the type of furnace. It was initially determined experimentally.

With radon released at the air intake, four samples were taken at the input point, giving a count as indicated in Fig. 3*b*, and ten were taken at the waste-gas sampling point (Fig. 3*a*), each sample having a duration of 10 sec. Four 10-sec. samples were required for the second seed (Fig. 3*c*). The time required for all the radon to pass the input point was therefore 40 sec.; 30 sec. elapsed before the radon traversing the full circuit was detected, and 100 sec. before all the radon had passed the sampling point.

The two seeds were of equal strength (5 mc.), and the second seed was broken in the culvert between the checkers and the reversing valve. The air-meter reading was 495,000 cu. ft./hr. and the furnace pressure, though not recorded, was, as indicated by sting at the doors, that normally encountered.

The following results were obtained by applying the previous equations:

Leakage	14·4%
Amount of radon returning	67·2%
Total blowout	18·4%
(all as percentage of the input radon)	
Total infiltration	24·9% (on input volume)
Ratio $\frac{\text{waste-gas volume}}{\text{input volume}}$	1·07
Air supply calculated from input count and standard count method	516,000 cu. ft./hr.

The volume change with combustion has been neglected and it has been assumed that the blowout preceded the infiltration. The reliable error has been calculated for all counts and in all cases except I_L the reliable counting error was $\pm 1\%$. For I_L the counting error was $\pm 5\%$.

Mixing Error—In the results quoted, the radon was thoroughly mixed as indicated by counts at different depths in the waste-gas culvert,* but in some experiments a mixing error was detected. If a mixing error of 1% had been present in addition to the counting error of 1%, the results would be :

Leakage	13·0–16·0% of input radon
Return radon	64·4–70·1% ,, ,, ,,
Blowout	14·0–22·3% ,, ,, ,,
Infiltration	17·5–31·8% ,, ,, volume
$\frac{\text{Waste-gas volume}}{\text{Input air volume}}$	1·035–1·095.

These calculations have been based on initial blowout followed by infiltration, but if the reverse occurred, the following results would be obtained :

Blowout	14·0–30·0% of input radon
Infiltration	17·5–40·0% ,, ,, volume.

The large error associated with values for total blowout and infiltration throughout the furnace system is apparent.

Straight-Through Valve

Because of the absence of bends with this type of valve, it was necessary to break the second seed at the top of the checkers to ensure adequate mixing. With the waste-gas sampling point near the valve, stratification of the radon leakage across the valve was observed, and so the sampling point was chosen as far away as possible. Even after doing this, however, stratification was still present on some furnaces, and with this type of valve the possible error in leak determination was larger than with a butterfly type.

Experimental Results—The results quoted were also taken on a 90-ton oil-fired furnace. Previous results had shown that the radon from the second seed and the radon leaking over the valve were not thoroughly mixed by the time the position of the sampling point was reached when this was in the waste-gas culvert in close proximity to the valve. Samples were therefore taken at a point just before the waste-heat boiler, *i.e.*, as far removed as possible from the valve.

Samples were taken from two depths separated by a distance of 2 ft., and the results showed that the counts could differ by 15% when radon was released in the culvert between the checker and the valve. The discrepancy was much reduced by releasing the radon at the top of the waste-gas checker, but a possible error† of 15% had to be accepted for the counts representing the leakage radon.

For an air-meter reading of 455,000 cu. ft./hr. and normal pressures throughout the system, the following results were obtained:

Waste-gas volume	630,000 cu. ft./hr.
Leakage	6·8 ± 1% of input radon
Blowout	0% of input radon
Infiltration	204,000 cu. ft./hr.

Blowout and infiltration values are included to indicate the calculated magnitude; the errors will be quite large, as shown previously.

Measurement of Infiltration

As an example of the application of this technique to the direct determination of infiltration, the measurement of the infiltration into the checker and uptake system of a 300-ton tilting furnace will be described. The system investigated (Fig. 4) consisted of a standard orifice to meter the air supply to a straight-through reversing valve, and conventional pit and stage uptakes. The checkers and uptake were plated and sprayed, and appeared to be very effectively sealed.

With radon released at the air intake, it was possible to determine

* It had previously been determined that no stratification existed at the input sampling point.

† This error will vary according to the size and construction of the furnace, and must be determined for each valve investigated.

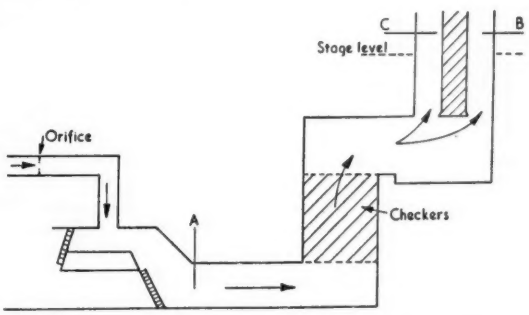

Fig. 4—Schematic arrangement of a furnace air system

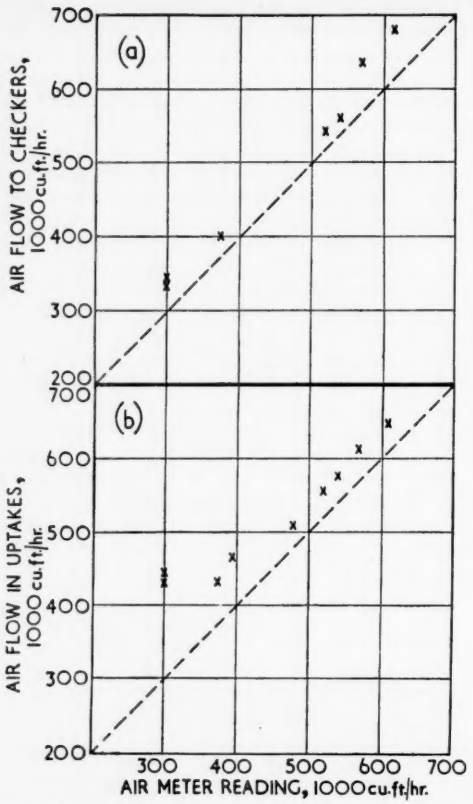

Fig. 5—Comparison of air-meter reading with air flow (*a*) to checkers, (*b*) in furnace uptake

(i) The ratio of the volumes flowing past any two points between the reversing valve and the bottom of the uptakes from the ratio of the total counts from samples taken at the two points

(ii) The ratio of volumes between the reversing valve and the top of the uptakes, only if no change in volume occurred after the division of the air stream between the two uptakes, because the amount of air flowing up each uptake* was unknown

(iii) The actual volumes at any point, provided that the loss of radon across the reversing valve was known and no volume change occurred after the slag pocket.

Experimental Procedure—Since it was desirable to measure the air flow as close to the furnace chamber as possible, preliminary measurements were taken to determine the radon concentration in the two uptakes 3 ft. above stage level.

Radon was released at the air intake, and samples were taken at *B* and *C*. The ratio of the counts indicated that the change in volume after the air stream divided was negligible, and consequently samples were taken from the pit uptake only for the main measurements. So that actual volumes could be determined, the valve leakage was measured in another series of experiments.

To determine the infiltration and volumes flowing in the air system, a radon seed (5 mc. strength) was broken before the fan at the air intake and samples were taken at *A* and *B*, with the air flow constant and fixed previously at the reading required on the air meter. The activity in each sample was then found as described.

The measurements were repeated at various air-meter settings so that the range 300,000–600,000 cu. ft./hr. was covered.

Results—The valve leakage measured over the range of flows required was constant and equal to 10% of the input radon.

The large and modern construction of the furnace culverts caused some difficulty with stratification in the waste-gas culvert, even when taking samples from the stack bottom, but a 20% error in the leakage radon samples changes the valve leakage figure by ± 2% only.

The results of the infiltration measurements are shown graphically in Figs. 5*a* and *b*, from which it can be seen that

(i) It was only at the low values of air-meter settings that infiltration was taking place after the reversing valve

(ii) Both the volume to the checkers and the uptake volume were higher than the air flow indicated† on the meter, even though 10% of the input had leaked across the valve.

CONCLUSIONS

Provided that thorough mixing of the radon has taken place at the sampling point, a technique has been developed with which it is possible to measure valve leakage, blowout, and infiltration on open-hearth furnaces.

Measurements may be taken at any position, whatever the nature of the furnace construction, gas temperatures are not required, and the errors involved, though dependent on the furnace investigated, are satisfactory.

Acknowledgments

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They are also indebted to the management and staff of Dorman, Long and Co., Ltd., and The Appleby-Frodingham Steel Company, at whose works the technique was developed, for the interest and assistance given at all times.

References

1. R. HAYNES: *J. Iron Steel Inst.*, 1952, vol. 170, pp. 149–152.
2. R. MAYORCAS and M. W. THRING: *Nature*, 1943, vol. 152, pp. 723–724; R. MAYORCAS and K. P. PERRY: "Some Aspects of Fluid Flow," pp. 216–226: 1950, London, Edward Arnold and Co.
3. E. W. VOICE, E. B. BELL, and P. K. GLEDHILL: *J. Iron Steel Inst.*, 1954, vol. 177, pp. 423–427.

* Previous measurements with Pitot tubes have shown that the pit uptake normally carries more air than the stage uptake.

† This could have resulted from an error in the air measuring system, from infiltration between the orifice plate and the sampling point *A*, or from a combination of the two. Investigation showed that, although the orifice had a basic tolerance of ± 3%, infiltration at the valve was possible.

Elimination of 'Stretcher Strains' in Mild-Steel Pressings

By B. B. Hundy, B.Sc., Ph.D., A.I.M.

SYNOPSIS

It is shown that temper-rolled mild-steel sheet contains high residual stresses; these stresses mask the yield-point elongation of the steel and enable it to be pressed after appreciable ageing without showing stretcher-strain markings. Other methods of eliminating stretcher straining, such as roller levelling or stretching the sheet through the yield-point elongation, do not induce such high stresses, and such sheet must not be allowed to age for more than a few hours if this defect is to be avoided. Both macroscopic and microscopic residual stresses can mask the yield-point elongation and, in general, it is best to process the sheet so as to give high stresses of both types. Only stretcher strains are marked by residual stresses, and the changes in the ductility, hardness, and strength during strain ageing are unaffected by the method of removal of the yield point.

Temper-rolled sheet is usually flattened in a roller leveller after rolling, and it is shown that if such levelling is carried out with the minimum intermesh of the rollers, the time for which the sheet can be stored without stretcher strains occurring on pressing is reduced. Roller levelling with the maximum intermesh, however, is not so detrimental as light levelling, and if the temper-rolling reduction is light it may even be beneficial. The effect of these levelling treatments can be explained in terms of modification of the residual-stress system imposed by temper rolling. 921

RESIDUAL STRESSES AND ELIMINATION OF 'STRETCHER STRAINS'

THE terms 'stretcher strains' or 'Lüders lines' are used to describe the flamboyant markings which sometimes appear on the surface of steel pressings during a light draw. Figure 15 shows an example of this defect in such a pressing, and it can be shown that the markings are caused by plastic yielding of some portions of the steel, whilst other parts are only strained elastically. The formation of this defect is intimately connected with the discontinuous yield point of mild steel (Fig. 1), and if this yield point can be removed the steel will not form stretcher strains on pressing.[1, 2] In general, it is known that the severity of the stretcher strains is dependent on the yield-point elongation of the steel sheet, a large elongation leading to very severe stretcher straining. This yield point, and hence the liability to form stretcher strains, can be removed by working the steel slightly before pressing. This is usually done by temper rolling, *i.e.*, by rolling to a reduction of 1–2%, but, provided that the yield-point elongation is not too large, roller levelling can also be used. This usually involves bending the sheet severely over a flexing roller and then flattening it by passing it through a series of staggered rollers. The yield point can also be removed by stretching the sheet to a strain greater than the yield-point elongation, but this is not much used in industry.

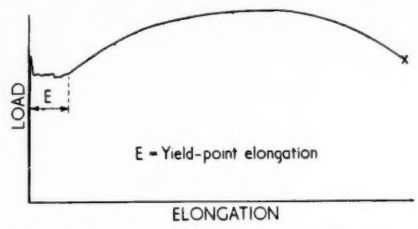

Fig. 1—Stress/strain curve of mild steel

If the steel sheet is allowed to rest at room temperature for some time after being worked to remove the yield point, it is found that the yield point returns and a pressing shows stretcher strains again. This phenomenon is called 'strain ageing' and it occurs to some extent in most mild steels. If the steel is stabilized with aluminium or vanadium during its manufacture, strain ageing does not occur and, once the initial yield point is removed, it does not return on resting at room temperature.[3–5] These special steels, however, are expensive and most of the steel used for pressings is not stabilized; they will not therefore be considered further in this paper.

It is found in practice that correctly temper-rolled sheet will press without showing stretcher strains after ageing for a much longer time than roller-levelled or stretched sheet; rolled sheet remains suitable for pressing for several weeks after processing, whereas the effect of stretching or roller levelling disappears after only a few days. This fact has been a major metallurgical mystery for many years.

Many hypotheses have been advanced to explain the discontinuous yield point and strain ageing of mild steel,[6] but it is now generally agreed that the Cottrell–Bilby theory[7] is the most probable. The essentials of this theory are that the interstitial carbon or nitrogen atoms are too large to fit easily into the regular iron lattice, and so they tend to segregate to positions where the lattice is expanded slightly by dislocations. This segregation or 'atmosphere' of solute atoms tends to lock the dislocations in place and makes plastic yielding, which involves movement of dislocations, more difficult. Once a dislocation has

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been torn away from its ' atmosphere ' it can travel under a lower force, and so the stress needed to cause plastic flow falls. The stress needed to tear dislocations away from their ' atmosphere ' is associated with the upper yield point, and the stress needed to cause further movement of the dislocations is associated with the lower yield point. Strain ageing is considered to be due to the migration of carbon or nitrogen atoms through the lattice to the dislocations so as to lock them in place as before. Provided that there is no large difference in the degree of cold work, this theory predicts that strain ageing should only be governed by the time and temperature of ageing and by the amount of carbon and nitrogen in solution, and should not be affected by the method of plastic deformation. On this basis, therefore, temper-rolled sheet should strain age at the same rate as roller-levelled or stretched sheet.

Polakowski[8] has shown that the yield-point elongation of mild steel can be masked by residual stresses, and it is believed that the different ageing behaviour of temper-rolled and roller-levelled or stretched steel sheet can be explained in terms of the residual stresses induced in sheet by temper rolling being higher than in sheet processed by either of the other methods. To see how these residual stresses can mask the yield point and prevent stretcher straining it is first necessary to examine the yielding in tension of annealed sheet or fully aged sheet containing no residual stresses.

As the steel is strained, all the grains are stretched elastically and there is a tendency for the dislocations to be torn away from their restraining ' atmospheres ' of carbon and nitrogen atoms ; eventually, aided by thermal fluctuations, this occurs in one place and the dislocations move through the crystal until they are stopped by a barrier, *e.g.*, a grain boundary. The pile-up of the dislocations at the grain boundary causes a high stress to act on the boundary at this point, and also through the boundary on the neighbouring grains. Thus, a neighbouring grain is acted on by this high stress as well as by the applied stress, and therefore yielding will occur in this grain at once. This process is repeated from grain to grain and yielding becomes cataclysmic. The yielding takes place almost instantaneously through the sheet thickness and gives rise to a Lüders line. As the steel is stretched further, this line broadens until it eventually covers the whole length of the specimen. Owing to the stress concentration factor at the edge, the spreading of the line takes place at the lower and not the upper yield stress. Once the Lüders line has spread to cover all the specimen, further stretching is uniform, with no localized plastic flow until necking starts.

Consider the case of mild-steel sheet containing macroscopic residual stresses. Figure 2 shows a hypothetical residual-stress distribution with tensile stresses at the surface and compressive stresses in the core of the sheet. If such a sheet is stretched, the actual load acting on a particular grain is the external load plus the residual stress acting at this point. In this case, the surface grains are acted on by the highest tensile stress, and a surface grain will probably yield first. If the internal stress gradient is steep enough, the stress concentration due to the pile-up of the dislocations at a grain boundary may not be high enough to cause yielding in the next grain away from the surface, and the external load would have to be raised before the yielding penetrated further. It seems, therefore, that all the surface grains will yield first and that the deformation will gradually penetrate towards the core as the stress is raised. Any tendency of the surface grains towards cataclysmic yielding will be restrained by the still-elastic core of the sheet. Steel sheet containing high residual stresses would therefore show a rounded stress/strain curve, rather than the usual discontinuous one, and would not give stretcher strains on pressing.

The essentials of this explanation, in brief, are that strain ageing takes place normally in temper-rolled sheet, giving rise to the usual increase in hardness and fall in ductility, but the yield-point elongation (and hence the formation of stretcher strains) is masked by the residual stresses in the sheet. It is doubtful whether it is possible to have residual stresses high enough to eliminate completely a very long yield-point elongation ; they will only reduce it to a certain extent. This is why even the most efficiently temper-rolled sheet eventually ages, although the yield-point elongation will be much less than that in a similar specimen without residual stresses. Only the effect of macroscopic residual stresses has been considered so far, but it is most probable that intergranular residual stresses will have a similar effect. As these can vary considerably from grain to grain, it is possible that in some cases these microscopic stresses may be more effective in masking the yield point than the macroscopic stresses.

A survey of the literature lends some support to this theory of the action of residual stresses, and the relevant work is discussed in the following section.

Previous Work

The work of Polakowski[8] provides the strongest evidence for the influence of residual stresses on the yield point of mild steel. He deformed steel specimens in a manner likely to induce residual stresses (*e.g.*, drawing, twisting, and surface rolling) and tested them after a moderate ageing treatment. No yield point could be seen. If, however, the surface skin of

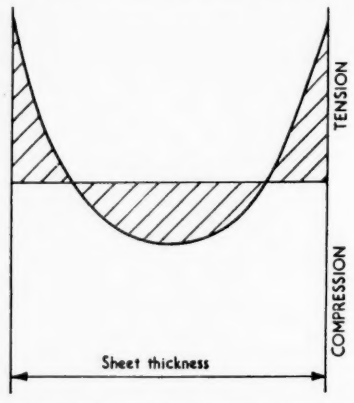


Fig. 2—Hypothetical residual-stress distribution in mild-steel sheet

the metal was removed by machining or if the specimen was stretched slightly, a discontinuous yield point appeared on ageing. These treatments would tend to reduce the residual stress, and so these experiments provide very strong support for the hypothesis outlined in the previous section. The hypothesis is further strengthened by the fact that Polakowski also found that the yield point could be restored in temper-rolled steel sheet by a slight stretch before ageing.

If mild steel is quenched from about 700° C., no yield point can be observed on testing in tension.[9, 10] Such a treatment would give rise to intergranular quenching stresses, and this provides support for the idea that microscopic stresses can also mask the yield point. Felmley, Hartbower, and Pellini[10] also showed that a yield point can be induced in quenched steel by stretching the specimen slightly before ageing ; this would modify the distribution of micro-stresses and render them ineffective in the direction of tensile strain, thus minimizing their masking action. Further evidence for the effect of intergranular stresses is provided by the work of Tipper,[11] who found that a yield point returned on ageing a sheet (prestrained in tension) for 30 min. at 250° C., if the test was carried out in the direction of prestraining. If, however, the sheet was tested in the transverse direction, no yield point could be seen, even after this most severe ageing treatment. The microscopic stresses locked up in a specimen prestrained in tension are oriented so that they are relatively ineffective if further testing is carried out in the same direction and they do not cause a fall in the elastic limit. If, however, testing is carried out in another direction, some grains will have internal stresses such that they yield at a very low applied stress, with the result that the plastic yielding is gradual and the yield point is masked. This effect is, of course, a reflection of the well-known Bauschinger effect.

Many investigators[12, 13] have shown that most mechanical-working processes induce residual stresses of some sort and that the stresses depend on the conditions of working. Baker, Ricksecker, and Baldwin[14] have shown, for example, that rolling can introduce surface tensile stresses equal in magnitude to 75% of the yield strength of the metal. Apparently no one has attempted to measure the stresses in roller-levelled sheet, but, by the nature of the process, it is to be expected that the residual stresses will be very small. Similarly, stretching the sheet should not give rise to any macroscopic residual stresses at all.

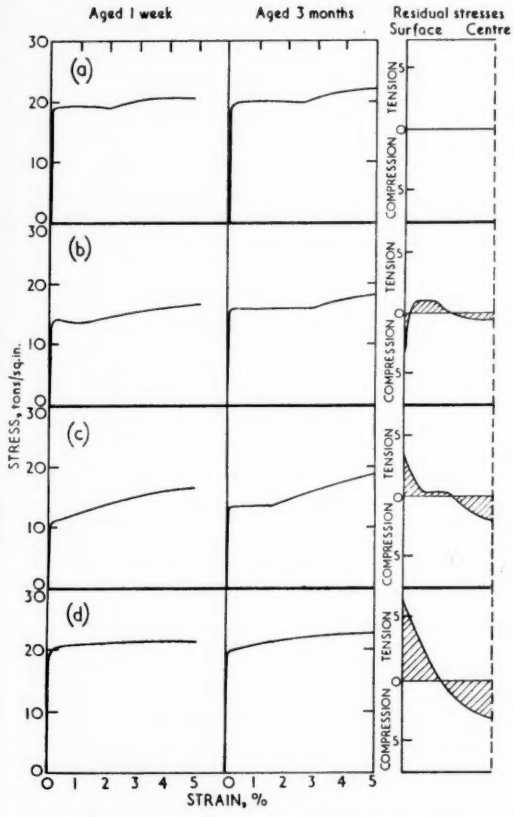


Fig. 3—Correlation of stress/strain curves after ageing with the residual stress in the sheet: (*a*) stretched 5%, (*b*) roller-levelled, (*c*) rolled 1·6%, (*d*) rolled 8%

Correlation of Ageing Behaviour with Residual Stresses

There is apparently a fair amount of evidence bearing on the effect of residual stresses on the yield-point behaviour of mild steel. However, no one has yet attempted to correlate exactly the residual stresses produced by temper rolling, roller levelling, or stretching with the ageing behaviour of the processed sheets. The aim of the work described in this paper was to do this, and to this end measurements of the residual stresses in mild-steel strip processed in various ways have been made and have been compared with the ageing behaviour of the strips. Although this work was primarily concerned with the effectiveness of the various methods of preventing stretcher strains in pressings, it was decided that the most convenient way of following the ageing process was by tensile testing. This method of following the ageing is permissible because, as mentioned earlier, there is a very close connection between the yield-point elongation in a tensile test and the formation of stretcher strains in a pressing.[1, 2] Thus, by measuring the yield-point elongation during the tensile test, a quantitative measure of the ageing can be obtained rather than the qualitative idea that would result from observation of the formation of stretcher strains.

In addition, it is also shown in the following section that the fundamental ageing process is not is prob-by the method of processing used and that it affected ably due to diffusion of carbon or nitrogen through the iron lattice, as suggested by Cottrell and Bilby.[7]

The mild-steel sheet (18 S.W.G.) used in the experiments described in the paper, was of extra-deep-drawing quality, with the following chemical composition : C, 0·056% ; Mn, 0·30% ; S, 0·032% ; P, 0·016% ; Sn, 0·037% ; Cu, 0·16% ; Ni, 0·07% ; N, 0·0044%. Microscopic examination showed that the steel was moderately clean and that the A.S.T.M. grain size, which was fairly uniform, was about 7. Strips 1½–2 in. wide were taken from a single sheet of

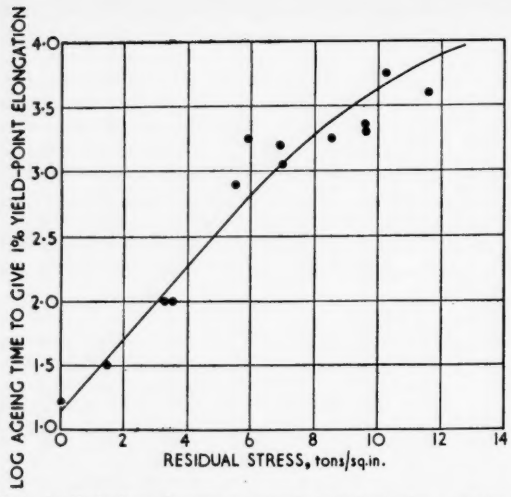


Fig. 4—Relation between strain-ageing time giving rise to yield-point elongation of 1% and magnitude of residual stress

this steel and were either temper-rolled, roller-levelled, or stretched, before ageing and testing.

Temper rolling was carried out on a 10 in. × 10 in. experimental mill at a rolling speed of 50 ft./min.; both the rolls and the strip were degreased with trichlorethylene before rolling. The reductions given to the strips varied from 0·7% to 10%. Roller levelling was done on an experimental roller leveller. No flexing roller was used in these experiments and it was found that the yield-point elongation was not completely removed by the levelling treatment. Tensile prestraining was done on a Hounsfield tensometer and a strain of 4–5% was given to all specimens; this strain was sufficient to take the strip completely through the yield-point elongation.

Tensile specimens according to B.S.485 were cut from these strips and were aged for various lengths of time in an oil bath at 58·5° C. before testing in tension. There is a simple relation between ageing at this temperature and at room temperature[15] and the times of ageing quoted in the paper are the equivalent ageing times at room temperature. The stress/strain curves were determined using a Hounsfield tensometer and a Lindley extensometer.

Specimens were also cut from the same strips for determination of the residual stresses. This was done by the usual method[13] of stopping off one face of the strip with wax and then etching away the other face. By measuring the change in curvature of the specimen as the thickness is reduced, it is possible to calculate the original residual-stress distribution. Typical residual-stress patterns for some of the specimens are plotted in Fig. 3, with the corresponding stress/strain curves after ageing for 1 week and 3 months.

The ageing behaviour of the specimens processed in these four different ways varied considerably. Heavily temper-rolled strip is more resistant to the return of the yield point than lightly rolled, roller-levelled, or stretched strip and this difference in ageing behaviour can be closely correlated with the residual-stress patterns. Thus, for a constant ageing time, the strip with the smallest yield-point elongation has the highest residual stresses and that with the lowest residual stresses has the longest yield-point elongation. This correlation between the magnitude of the residual stresses and the yield-point elongation was found to be generally true for all the specimens tested. The ageing time needed to give a 1% yield-point elongation after a particular treatment was estimated by interpolating the results of the ageing

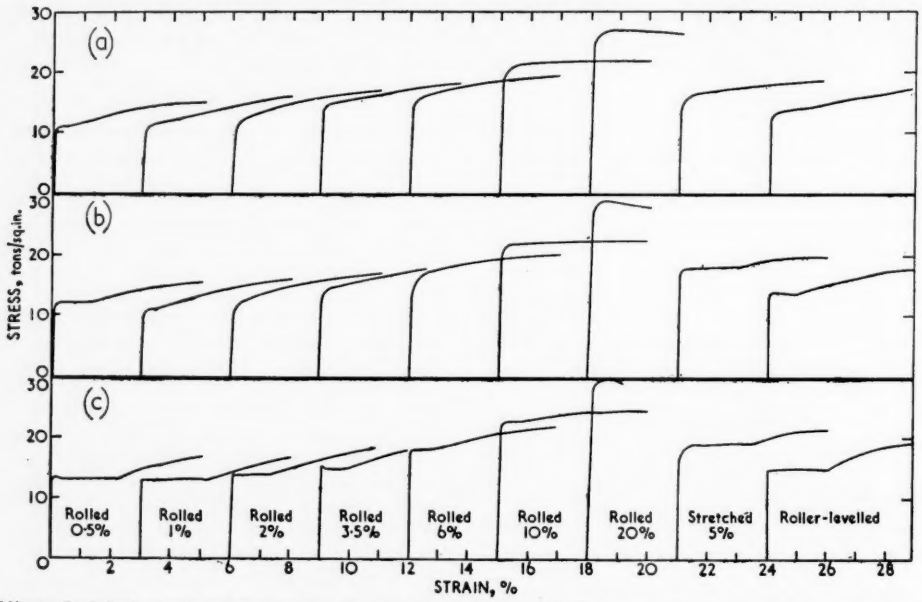


Fig. 5—Effect of ageing at room temperature for (*a*) 6 hr., (*b*) 1 week, (*c*) 6 months on stress/strain curves of mild steel deformed in different ways

tests, and in Fig. 4 the logarithm of this time is plotted against the residual stress in the sheets. The stress plotted is the sum of the maximum tensile stress and the maximum compressive stress in a particular specimen. There is a rough correlation between the ageing time and the residual stress, although the scatter in the results is rather large. The scatter is most probably due to the fact that this plot does not take account of the microscopic residual stresses or of the shape of the macroscopic residual-stress curve.

A number of other tests confirmed Polakowski's findings[8] that the return of a yield point in temper-rolled sheet could be accelerated by either stretching slightly or by etching away about 0·005 in. of material from each face of the strip. It was also found that light roller levelling had a very similar effect, and a full report of this work is given in the second part of this paper.

Effect of Method of Working on Intrinsic Strain-Ageing Behaviour

The work described in the previous section shows fairly conclusively that residual stresses are a most important factor in determining the strain-ageing behaviour of mild steel. However, it is not certain whether the intrinsic ageing behaviour is also affected by the method of working. According to the theory outlined in the introduction, the residual stresses induced by working the steel mask the effect of ageing on the yield point, but do not affect the actual basic ageing process. Thus, different methods of working should not affect the changes in ductility, hardness, U.T.S., or limit of proportionality which occur on ageing. The rise of the limit of proportionality is easily measured and, as it is comparatively large, it was used as a criterion of the basic ageing process.

Steel strips were (i) rolled various amounts, (ii) roller-levelled, and (iii) strained in tension, and the stress/strain curves were determined after ageing for various times at room temperature. Figure 5 shows the curves obtained for a number of the strips worked in various ways, for three different ageing times. As expected, there is a marked difference between the samples ; some specimens show a large yield-point elongation, whereas other stress/strain curves are rounded with no yield point at all.

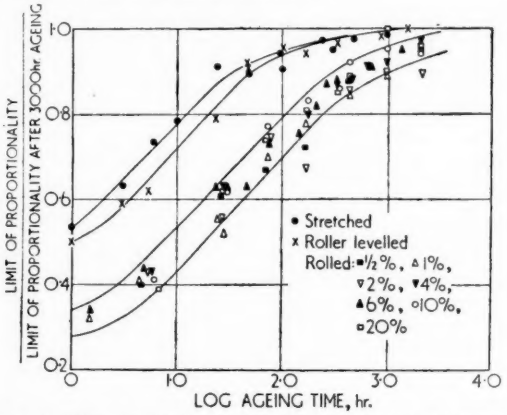


Fig. 6—Rise in limit of proportionality of deformed mild steel on ageing at room temperature

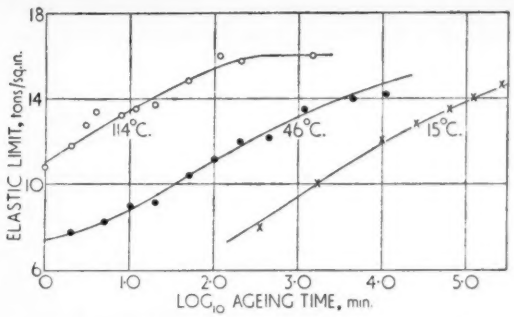


Fig. 7—Rise in elastic limit of mild steel rolled 4% and aged at different temperatures

The rise in limit of proportionality during ageing is shown in Fig. 6. The limit of proportionality was taken to be the point where the stress/strain curve departs from linearity, and in Fig. 6 it is expressed as a proportion of the limit of proportionality of a similar specimen after ageing for 6 months. This enables all the results to be shown easily on one diagram. The results fall into three distinct groups—rolled, roller-levelled, and stretched—and the three curves are essentially parallel to each other until near the end of the ageing process. This suggests that the rate of ageing is approximately independent of the method of working and provides strong evidence in favour of the idea that there is no fundamental difference in the ageing of steel worked in different ways.

It has been shown[16] that the activation energy for strain ageing after stretching agrees with the measured values for the diffusion of carbon or nitrogen in α-iron, so that a determination of the activation energy of strain ageing after temper rolling should decide definitely if the ageing process is the same as after stretching. Specimens were rolled 4% and were aged at room temperature (15° C.), 46° C., and 114° C. The limit of proportionality was estimated from the stress/strain curves determined at various ageing times, and the results are plotted in Fig. 7. The activation energy was determined by measuring the ageing time at each temperature which gave rise to a certain value of the limit of proportionality (*i.e.*, a certain degree of ageing) and then plotting the logarithm of this time against the reciprocal of the absolute ageing temperature. The activation energy is given by the slope of this curve, and this was measured for a number of different levels of ageing. The values of 18,100–20,000 cal./mole obtained agree quite well with the latest figures for the diffusion of carbon or nitrogen in ferrite. Wert[17, 18] has found that the activation energy for the diffusion of carbon in iron is 20,100 cal./mole and that for the diffusion of nitrogen is 18,200 cal./mole.

It thus seems, at least for the variety of conditions used in the present work, that the intrinsic strain-ageing process is unaffected by the method of working and, therefore, that the extent of return of the yield point after ageing is dependent only on the residual stresses induced in the sheet by the working process. It can also be assumed that the tendency to form stretcher strains is governed by the length of the

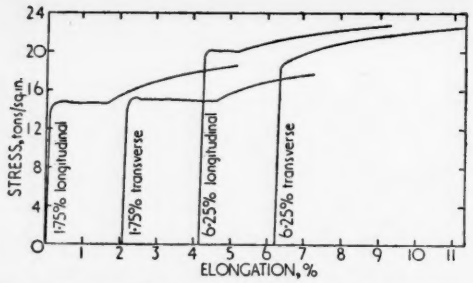


Fig. 8—Effect of direction of testing on shape of stress/strain curve of rolled-steel strip aged for 6 months

yield-point elongation, and therefore that this too is dependent on the residual stresses.

Discussion

The experiments described in this paper, together with the previous work, show fairly conclusively that both macroscopic and microscopic residual stresses can have a very profound effect on the shape of the initial part of the stress/strain curve of mild steel. The effectiveness of a particular working process with regard to the elimination of stretcher strains in subsequent pressing operations will therefore depend to some extent on the magnitude of the residual stresses induced by that process.

The macro-stresses induced by rolling or roller levelling are essentially unidirectional and the resistance to ageing in the transverse direction might therefore be expected to be low. However, the work of Tipper[11] suggests that micro-stresses can be even more effective than macro-stresses in masking the yield point, and it is quite possible that micro-stresses will give freedom from stretcher straining in the transverse direction. Temper rolling is essentially a process for elongating the sheet and will lead to an internal micro-stress system which is very similar to that induced by stretching. These micro-stresses are oriented so that when the straining direction is different from that of prestraining, some grains will yield at very low applied stresses and others only at high applied stresses ; thus, in this case, the yield-point elongation will be very effectively masked. When the direction of testing is the same as, or similar to, that of prestraining, then, provided that no macro-stresses are present, all the grains will yield at about the same applied stress, giving rise to a pronounced yield-point elongation. For efficient elimination of stretcher straining, therefore, it is desirable to induce large macro-stresses in the rolling direction and large micro-stresses in the transverse direction.

Very little information is available on the factors affecting the magnitude of micro-stresses, and it is difficult to predict the optimum working methods which will give rise to large stresses. Greenough[19] has described how the residual lattice strain in a polycrystalline metal increases with the amount of tensile strain, which implies that the residual micro-stresses also increase with strain. Thus, increasing the rolling reduction should lead to a more efficient masking of the yield-point elongation in the transverse direction. The macro-stresses also increase with reduction, so that the resistance to the return of stretcher-strain markings in both the transverse and the rolling directions should increase as heavier temper-rolling reductions are used.

Some experiments were carried out which confirmed this predicted behaviour. Strips 7 in. wide were reduced in thickness by 1·75% and by 6·25% and standard tensile specimens were cut from these strips in the transverse and longitudinal directions. Tests were carried out after ageing for various periods and Fig. 8 shows the stress/strain curves obtained after ageing for 6 months. The yield-point elongation was determined from all the curves and is plotted against the logarithm of the ageing time in Fig. 9. It can be seen that the yield-point elongation in both the rolling and the transverse directions decreases with an increase in the reduction, the decrease being most marked in the transverse direction. Uniform behaviour in both directions will probably be obtained at some reduction between the two investigated, and theoretically this would probably be the best reduction for temper rolling. However, the reduction is limited in practice by the fact that the sheet should have as high a ductility as possible, and this ductility is markedly reduced by an increase in the temper as well as by ageing. For instance, if annealed steel has a total elongation of 43% in a tensile test, rolling 1% and ageing for 6 months can reduce this to 38·5%, and rolling 4% and ageing can reduce it to 31·5%.

It might prove possible to reduce the optimum reduction to a certain extent by varying the conditions of rolling, but at present there is little information available that would confirm this point. A little work has been carried out on the effect of the roll size and finish on the magnitude of the macroscopic stresses, but no one has examined the effects of these variables on the magnitude of the microscopic stresses. Baker, Ricksecker, and Baldwin[14] suggest that the residual stresses induced by cold-rolling are dependent on the geometry of the process and that they are raised by increasing the thickness of the rolled stock. The bearing bronze used by these investigators varied from $\frac{1}{8}$ in. to 2·0 in. in thickness, and so their results cannot be applied directly to the temper rolling of thin sheet steel. However, it is quite possible that smaller rolls would increase the magnitude of the residual stresses and thereby lead to more efficient temper rolling. Some evidence in favour of this idea is given by the work of Hayes and Burns,[20] who showed that a yield-point elongation of 5% was removed by 0·8% reduction with 4-in. rolls, whereas a reduction of 2·0% was needed with 26-in. rolls. Experiments

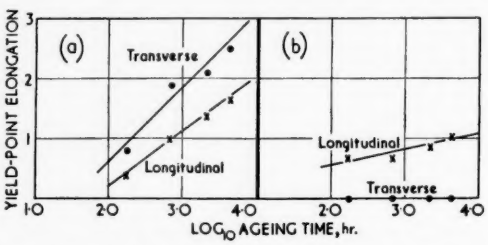
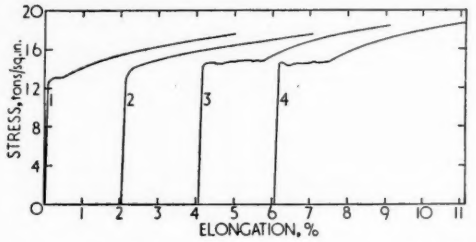


Fig. 9—Effect of direction of testing on yield-point elongation of mild steel rolled (*a*) 1·75% and (*b*) 6·25% after ageing

were made to determine the effect of roll size on the ageing of temper-rolled strip. Two different roll sizes, $3\frac{1}{8}$ in. and 6 in. dia., were used and the temper-rolled strips were aged for various times up to 12 months. Four of the stress/strain curves obtained are shown in Fig. 10, and it can be seen that after an equivalent ageing time the yield-point elongation is shorter for the strip rolled with the smallest rolls ; *i.e.*, temper rolling with small-diameter rolls is most efficient. The yield-point elongation was determined for each reduction at various ageing times and was plotted against the logarithm of the ageing time. The ageing time needed to give a yield-point elongation of 1% was estimated from these plots and the logarithm of this ageing time is plotted against the rolling reduction in Fig. 11. There is no doubt whatsoever that the 3-in. rolls are more efficient in preventing a return of the yield point than the 6-in. rolls ; this is probably due to a higher residual-stress level imposed by the smaller rolls. Hayes and Burns also showed that sheet with a smooth polished surface required more temper rolling to eliminate the yield-point elongation than similar sheet with a mat finish ; this agrees with practice in the tinplate industry, where temper rolling is normally done with rough rolls.

The most efficient method of temper rolling therefore appears to be to use small rough rolls, but temper rolling is usually carried out at a moderately high speed and the question of dissipation of the heat evolved during rolling might easily be a difficult problem with small rolls. The manufacturer must also consider the surface finish of the sheet, which might be adversely affected by rough rolls. The importance of this point is shown by the fact that temper mills using very rough rolls are often built in tandem with a second stand of polished rolls to improve the surface finish.[21]

Although there are difficulties, it should be possible to improve the efficiency of temper rolling and thus lengthen the time for which steel sheet can be stored without the fear of stretcher strains occurring during pressing. It must be realized, however, that in practice temper rolling is invariably followed by roller levelling to flatten the sheet, which is likely to reduce the safe storage time of the most efficiently rolled sheet. Nevertheless, an improvement in the efficiency of temper rolling would allow lighter reductions to be used, with a consequent improvement in ductility,



Curve	Deformation, %	Roll Dia., in.	Ageing Time
1	2·5	6	1 week
2	2·5	3	,,
3	1·7	6	3 months
4	1·7	3	,,

Fig. 10—Effect of roll size on shape of stress/strain curve of rolled-steel strip

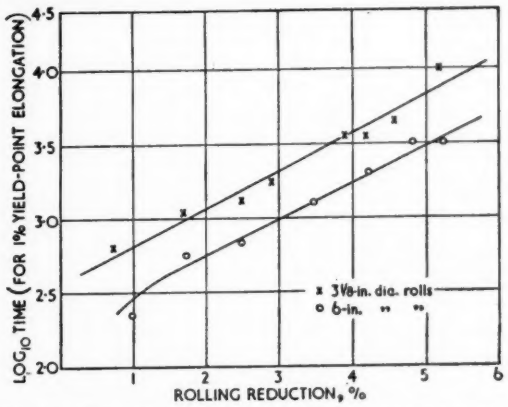


Fig. 11—Effect of roll size on ageing time needed to give 1% yield-point elongation

and it is therefore desirable to improve the practice of temper rolling whenever possible.

The yield point in temper-rolled sheet has often returned to a slight extent by the time the sheets reach the press shop and the sheets are usually put through a roller leveller to remove this before pressing. Why, therefore, should such machines not be used for processing annealed sheet directly, without the intermediate stage of temper rolling? Such a procedure would have definite advantages ; owing to the elimination of the temper mill, the cost of the sheet would be lower, and, more important, the sheet would have its maximum ductility and so could be used for difficult draws, instead of the more expensive stabilized steels. At present, however, the roller levellers in use in the pressing industry are not capable of removing the usual yield-point elongation of 4–5% and, although they could probably be improved somewhat in this respect, there is the problem of fluting to be considered, which can completely spoil the appearance of the sheet. It seems, therefore, that there is scope for a cheap efficient machine, probably based on the leveller principle, which could be used in the press shops to process annealed steel sheet so as to prevent stretcher straining during pressing. This machine would not necessarily have to induce very high residual stresses, as the steel would be pressed soon after processing, but it should remove the yield-point elongation without appreciably reducing the ductility of the sheet.

EFFECT OF ROLLER LEVELLING ON AGEING OF TEMPER-ROLLED STRIP

Sheet that is temper-rolled to prevent the occurrence of stretcher strains is normally roller-levelled immediately after rolling, before dispatching to the user. It was thought this practice would probably alter the magnitude and distribution of the residual stresses in the rolled sheet and might therefore affect its ageing behaviour. A number of experiments were carried out to determine whether roller levelling did affect the rate of return of stretcher straining in temper-rolled sheet and if variations in the levelling conditions had any effect.

The steel used was a 20 S.W.G. open-hearth mild rimming steel with the following chemical composition:

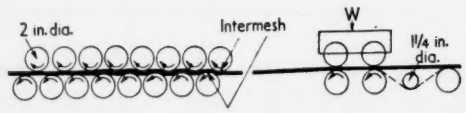


Fig. 12—Schematic layout of experimental roller leveller. Arrows indicate driver rolls

C, 0·042% ; Mn, 0·36% ; S, 0·034% ; P, 0·012% ; N, 0·004%. The A.S.T.M. grain size was about 8 and microscopic examination showed that the steel was moderately clean.

Temper Rolling Followed by Roller Levelling

Strips cut from the same mild-steel sheet were temper-rolled 0·75%, 1·5%, 2·2%, or 3·0% at a speed of 50 ft./min. and were tested either in the as-rolled condition or after roller levelling lightly or heavily. Roller levelling was carried out on a small experimental leveller, which is shown schematically in Fig. 12. Strip would just pass through the leveller at an intermesh of 0·13 in. and this setting was used for heavy roller levelling. Light roller levelling was taken to be the minimum intermesh at which flattening occurred and was found to be about 0·06 in. These two roller-levelling treatments gave quite different amounts of cold-working to the steel strips. This is demonstrated in Fig. 16, which shows the back-reflection X-ray diffraction photographs of annealed strips levelled at the two different settings. The difference in the amount of break-up of the diffraction spots in the two photographs, which is quite marked, is a measure of the difference in working.[22]

Tensile tests were carried out after ageing the processed strip at 58·5° C. for the equivalent of 1 day, 2 days, 1 week, 1 month, 3 months, and 6 months[15] and some of the results are shown in Figs. 13 and 14. It was found that the effect of roller levelling depended on the rolling reduction and that it became more detrimental as the reduction was increased.

Figure 13 shows some of the stress/strain curves obtained on ageing specimens rolled 0·75%. If the length of the yield-point elongation is taken as a criterion, it can be seen that both heavy and light roller levelling are beneficial, at least in the early stages of ageing. This is because in this case temper rolling does not completely eliminate the yield-point elongation and the levelling treatments help to reduce this. In Fig. 14, however, it can be seen that both the levelling treatments accelerate the return of the yield point in strip temper-rolled 3%. Light roller levelling was always found to be more detrimental than heavy.

The data from all the stress/strain curves are shown in Fig. 17, where the length of the yield-point elongation is plotted against the logarithm of the ageing time. Experience has shown that experimental points plotted in this way usually fall roughly on a straight line, and so lines have been drawn through the points in this diagram. The effectiveness of particular combinations of rolling and roller levelling, in regard to the suppression of the yield point, can be judged by estimating the time for which the strip can be aged before a certain yield-point elongation (say, 1%) returns. More efficient rolling and roller levelling leads to an increase in the ageing time. The logarithm

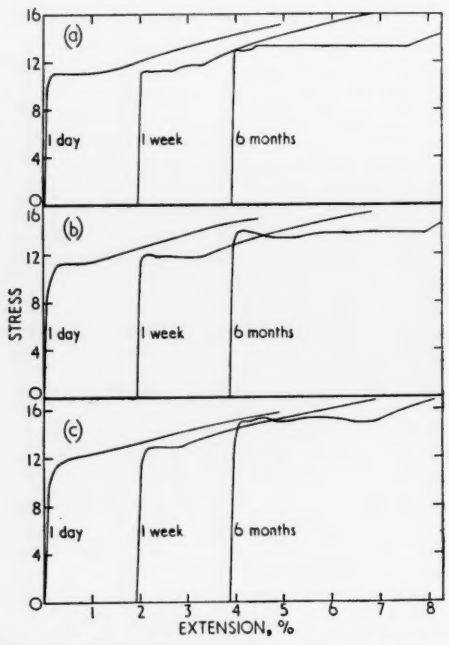


Fig. 13—Effect of roller levelling on stress/strain curve of steel (*a*) rolled 0·75%, (*b*) rolled 0·75% and lightly roller-levelled, (*c*) rolled 0·75% and heavily roller-levelled.

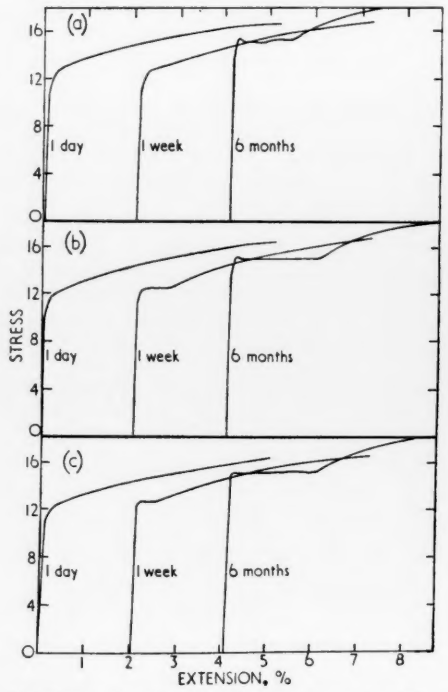


Fig. 14—Effect of roller levelling on stress/strain curve of steel (*a*) rolled 3%, (*b*) rolled 3% and lightly roller-levelled, (*c*) rolled 3% and heavily roller-levelled

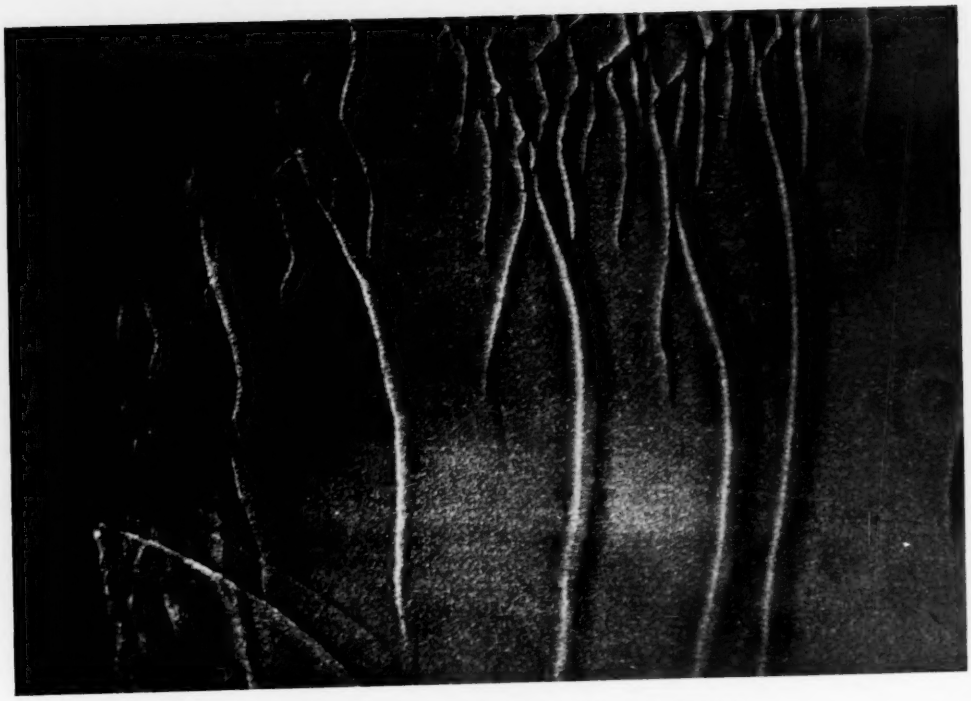
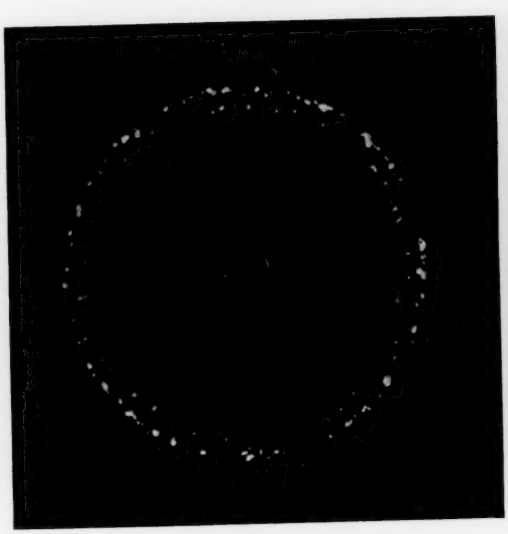
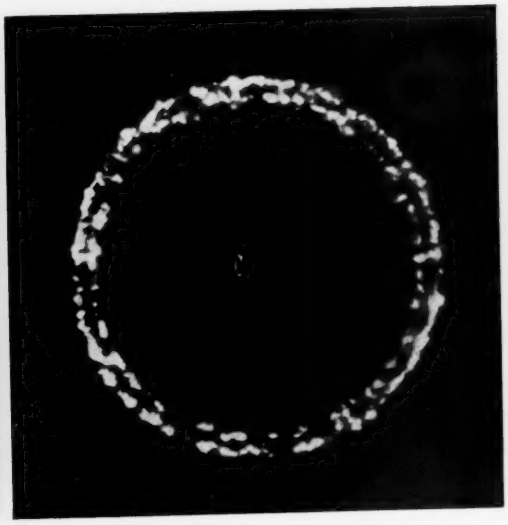


Fig. 15—Stretcher strains in a mild-steel pressing

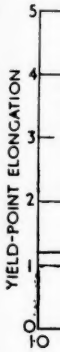
(a)





(b)

Fig. 16—(310) back-reflection diffraction patterns from strip roller-levelled (*a*) lightly, (*b*) heavily


YIELD-POINT ELONGATION
5
4
3
2
1
0
10

of the ageing time needed to give a 1% yield-point elongation is plotted in Fig. 18 against the temper-rolling reduction. Straight lines are drawn through the points for each of the three combinations of rolling and roller levelling : (*a*) temper rolling only ; (*b*) rolling + light roller levelling ; (*c*) rolling + heavy roller levelling. In general, the ageing time increases with the rolling reduction, but roller levelling appears to reduce the rate of increase of the ageing time with reduction. At low reductions it appears to be beneficial to roller-level heavily, as this treatment increases the ageing time. The temper rolling was probably not too efficient at the low reductions, and under these conditions it seems that the extra work introduced by the heavy roller levelling counteracts any detrimental effect that it might have. At higher reductions temper rolling is more efficient and the extra work introduced by levelling is not so important ; in this case roller levelling is very definitely detrimental.

The ductility of the rolled sheet did not seem to be affected by either light or heavy roller levelling, although the heavily tempered strip was slightly less ductile than that which was lightly tempered. There was a distinct fall in the ductility and a rise in the tensile strength on ageing. The average fall in the elongation after ageing for 6 months was about 6% and the rise in the tensile strength was about 0·6 tons/sq. in. The reduction in ductility was about the same for all the samples, with perhaps a slightly smaller reduction in the lightly tempered material.

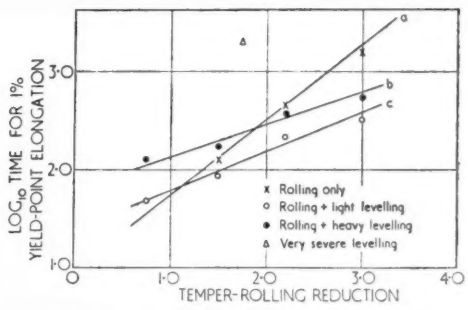


Fig. 18—Effect of various treatments on ageing time needed to produce 1% yield-point elongation

Temper Rolling and Roller Levelling Followed by Severe Roller Levelling

Most steel sheet is temper-rolled lightly and flattened at the mill and is then dispatched to the press shops. The sheet is usually pressed as quickly as possible after receipt, but often there is some delay and this, together with the time the sheet is in transit from the mill to the press shop, means that the yield point may return slightly by the time the steel is used. The sheet is therefore usually roller-levelled again at the press shop to remove the yield point and prevent stretcher straining during pressing. This sequence of operations was imitated in the laboratory by temper rolling 1·7% and then roller levelling with the maximum intermesh. The strips were aged for 1 month and were then put through the leveller again. On this occasion the strips were passed under the flexing roller before levelling (Fig. 12) ; this is the usual method of levelling used in the pressing industry and is naturally more severe than levelling without flexing. Tests were then carried out after ageing for various times.

A number of the stress/strain curves obtained are plotted in Fig. 19. The yield-point elongation of just over 1% is removed completely by the flexing and levelling treatment and does not return to this extent until after ageing for 3 months. Figure 20 shows the yield-point elongation plotted against the logarithm of the ageing time, and comparison with Fig. 17 shows that the return of the yield point is retarded as efficiently by this treatment as by temper rolling 3%. This is rather surprising, as it is generally believed that this type of roller-levelling treatment accelerates the return of the yield point.

This severe treatment did not seem to affect the ductility of the sheet appreciably ; Fig. 21 shows that the total elongation is not noticeably affected and the uniform elongation is actually increased slightly. The sheet might therefore be expected to withstand a slightly more severe drawing operation immediately after this treatment than if pressed before levelling.

Discussion

It is obvious from the results presented in the previous section that the ageing behaviour of temper-rolled steel sheet is profoundly affected by roller levelling and that the effect is dependent on the conditions of levelling. Very light roller levelling generally accelerates the return of the yield point whereas, at the other end of the scale, flexing and roller levelling, which is a very severe treatment, apparently delays the yield-point return. None of these levelling treatments seems to affect the ductility appreciably ; this is rather surprising, as the surface layers of the sheet would be expected to be worked appreciably by the reversal flexing during levelling.

It was pointed out earlier that modification of the residual-stress distribution in the steel sheet would affect the ageing behaviour, and it was thought

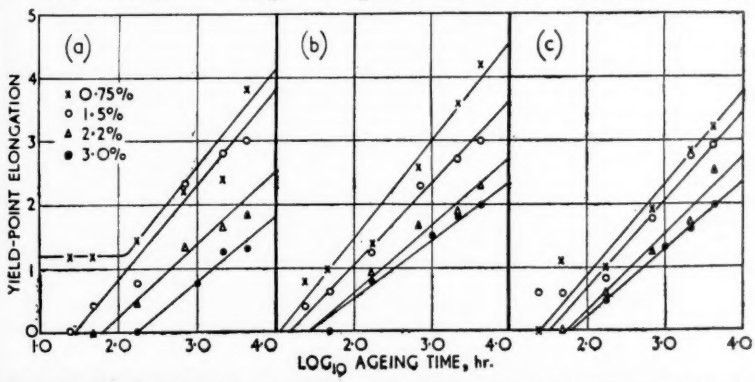


Fig. 17—Effect of ageing on yield-point elongation of (*a*) temper-rolled, (*b*) rolled and lightly roller-levelled, (*c*) rolled and heavily roller-levelled strip

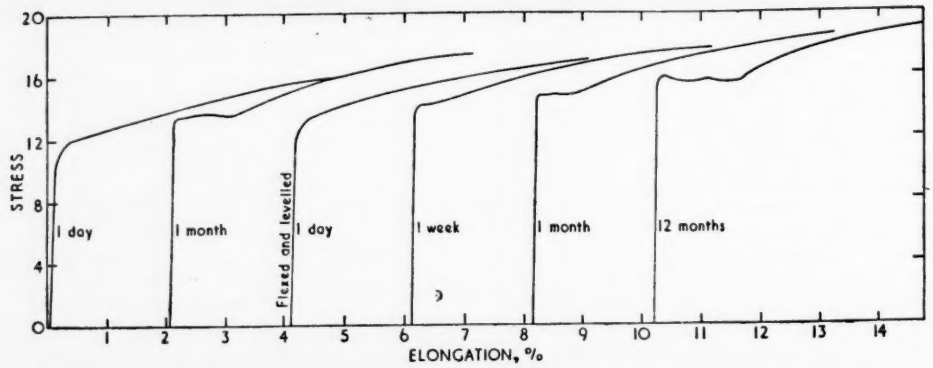


Fig. 19—Effect of sequence of working and ageing operations on the stress/strain curve of mild steel rolled 1·7% and heavily roller-levelled

that the effect of roller levelling could probably be explained on this basis. Measurements were therefore made of the residual stresses in specimens that were (*a*) rolled 3%, (*b*) rolled 3% and lightly roller-levelled, (*c*) rolled 3% and heavily roller-levelled, and (*d*) rolled 1·7%, heavily roller-levelled, aged 1 month, and then flexed and levelled. The residual-stress distribution was determined by the usual method of etching away one face only of the strip and measuring the change in curvature as the thickness of the strip is decreased.[13] The results obtained are shown in Fig. 22. There is no doubt that roller levelling greatly modifies the residual-stress distribution. Light roller levelling does not completely eliminate the residual stresses which were induced by rolling, but it decreases them to a certain extent, as well as inducing a high compressive stress in the surface of the sheet. Heavy roller levelling practically eliminates all the rolling stress, leaving only a very small compressive stress in the core of the sheet, as well as introducing a higher surface compressive stress. Flexing followed by moderate roller levelling induces a completely different stress pattern, with a high surface compressive stress and a high tensile stress in the core. The surface compressive stress due to roller levelling is confined to a very thin layer and would not be expected to be very effective in masking the yield-point : the restraining effects due to the still-elastic surface layers would probably not be large enough to prevent the cataclysmic yielding of the rest of the metal. Thus, if this point is taken into consideration, it can be seen that the flexed and levelled strip has a higher level of residual stresses (as indicated by the area under the curves) than the temper-rolled strip, and this in turn has higher stresses than the rolled strip which was roller-levelled lightly. Thus, of these three strips, the flexed and levelled specimen would be expected to be the most resistant to a return of the yield-point and the lightly roller-levelled specimen to be the least resistant. Reference to Figs. 18 and 20 shows that these strips behave as expected.

On this basis, strip heavily roller-levelled after temper rolling should be the least resistant to ageing because, apart from the high skin stress, the general stress level is low, It was found, however, that heavy roller levelling was generally superior to light levelling. This anomalous behaviour could be explained if heavy roller levelling introduces higher micro-stresses into the temper-rolled strip, and some support for this is given by measurements of the limit of proportionality of the rolled and roller-levelled strips. A higher level of micro-stresses should lower the limit of proportionality (the Bauschinger effect), and it was found that heavy roller levelling generally reduced the proportional limit of temper-rolled specimens by about 0·85 tons/sq. in., whereas light roller levelling raised it by about 0·1 tons/sq. in.

It seems, therefore, that the effect of roller levelling on the ageing of temper-rolled strips may be explained on the basis of the modification of both the macroscopic and microscopic residual stresses in the sheets.

Raising the temper-rolling reduction above 1½% is said to reduce the ductility of the temper-rolled sheet to too low a value, and normally this is the maximum reduction used in temper mills. The work reported in this paper suggests that, in this range, heavy roller levelling helps to retard the return of the yield point,

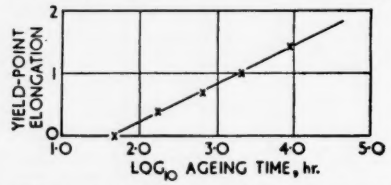


Fig. 20—Effect of ageing on yield-point elongation of steel strip rolled 1·7% and heavily levelled, aged 1 month, flexed, and levelled.

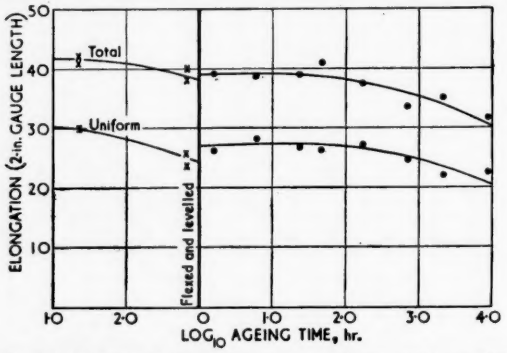


Fig. 21—Effect of sequence of working and ageing operations on ductility of steel strip rolled 1·7% and levelled

whereas light roller levelling accelerates it. However, the actual positions of the lines in Fig. 18 are probably dependent on the temper-rolling conditions. The commercial temper mills are probably more efficient than the experimental mill used in these experiments and it is possible, in practice, that curve *a* in Fig. 18 will be displaced upwards. Curves *b* and *c* might also be displaced, but it is doubtful whether either of these will be displaced as much as the curve for temper rolling only. It might be found advisable in practice, therefore, in some special cases to dispatch the steel in the as-rolled condition without levelling at all. Normally, however, it will not be feasible to dispense with levelling, and in this case the present work suggests that the roller levelling should be as heavy as possible.* This point of view is supported by some results of Polakowski.[8] He showed that bending to and fro over a 4-in. roll (equivalent to a very severe roller-levelling operation) prevented the return of a yield point in temper-rolled mild steel for at least 30 min. at 250° C. (equivalent to several years at room temperature). A yield-point elongation of 1·5% returned on ageing the as-rolled sheet for the same time. This, together with the results obtained using a severe flexing and levelling treatment, suggests that it might be advantageous to use very heavy levelling treatments after temper rolling ; care would have to be taken, however, to see that the ductility was not impaired by this treatment. In practice it will probably be easier to obtain heavy roller-levelling conditions by using small rolls rather than by using a large degree of intermesh.

On the whole, the work described in this paper suggests that there is an optimum combination of temper rolling and roller levelling that will give the maximum resistance to the return of the yield-point (and therefore to stretcher straining), together with the maximum ductility. This combination, however, will probably have to be determined separately for each particular temper mill under consideration.

CONCLUSIONS

(1) Temper-rolled mild steel can be allowed to age for a longer time, without showing stretcher strains on pressing, than either roller-levelled or stretched sheet. It has been shown that this is due to the higher residual stress introduced into the sheet by the rolling process.

(2) These residual stresses mask the yield-point elongation, but the changes in strength and ductility which occur on strain ageing were found to be independent of the working process.

(3) Macroscopic residual stresses are mainly responsible for masking the yield point in the rolling direction, but microscopic intergranular stresses probably mask the yield point in the transverse direction.

(4) The efficiency of temper rolling can be increased to a certain extent by using small rolls, and there are indications that a rougher roll finish will have a similar effect.

(5) Light roller levelling (*i.e.*, using a small amount of roll intermesh or large rollers) can accelerate the return of the yield point in temper-rolled steel sheet. This is probably due to the levelling treatment causing a reduction in the general level of residual stresses.

(6) Heavy roller levelling is not so detrimental to the ageing behaviour of temper-rolled sheet as light levelling, and in some cases may be advantageous. Although this treatment reduces the residual-stress level to an even lower value than light levelling, there is some evidence that it increases the microscopic

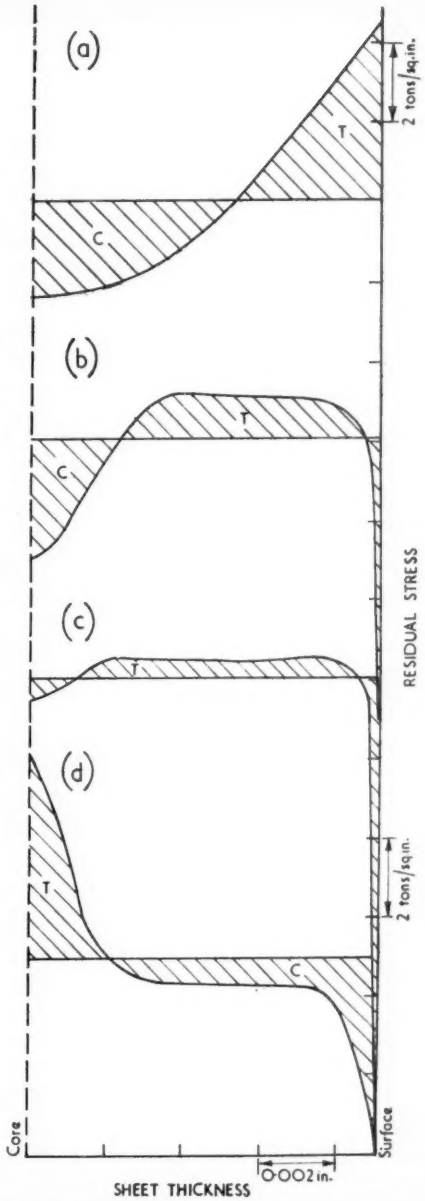


Fig. 22—Effect of roller levelling on residual stresses in rolled strip: (*a*) temper-rolled only, (*b*) lightly roller-levelled, (*c*) heavily roller-levelled, (*d*) flexed and levelled

*Honeyman[33] has pointed out that under certain conditions it might prove beneficial to use a very light levelling treatment which would just flatten the sheet without reducing the rolling stresses appreciably.

residual stresses, and it is these that help to mask the yield point.

Acknowledgments

The author would like to thank Mr. H. Edwards, of John Summers and Sons, Ltd., and Mr. A. J. K. Honeyman, of the Steel Company of Wales Ltd., for generously providing the steel used, and Professor H. W. Swift, of Sheffield University, for the use of the experimental roller leveller. Acknowledgments are also due to Mr. T. D. Boxall, Mr. D. Burton, and Mr. B. Coldwell for their careful experimental work.

References

1. R. L. KENYON and R. S. BURNS : *Transactions of the American Society for Steel Treating*, 1933, vol. 21, pp. 577–601.
2. J. WINLOCK and R. W. E. LEITER : *Trans. Amer. Soc. Mech. Eng.*, 1939, vol. 61, pp. 581–585.
3. G. F. COMSTOCK : *Sheet Metal Ind.*, 1945, vol. 22, pp. 2104–2108.
4. K. DIES : *Arch. Eisenhüttenwesen*, 1943, vol. 16, pp. 333–340.
5. S. EPSTEIN, H. J. CUTLER, and J. W. FRAME : *Trans. Amer. Inst. Min. Met. Eng.*, 1950, vol. 188, pp. 830–834 ; *J. Met.*, 1950, vol. 2, June.
6. J. R. LOW, jun., and M. GENSAMER : *Trans. Amer. Inst. Min. Met. Eng.*, 1944, vol. 158, pp. 207–249.
7. A. H. COTTRELL and B. A. BILBY : *Proc. Phys. Soc.*, 1949, vol. 62, ser. A, pp. 49–62.
8. N. H. POLAKOWSKI : *J. Iron Steel Inst.*, 1952, vol. 172, pp. 369–376.
9. N. P. ALLEN, W. P. REES, B. E. HOPKINS, and H. R. TIPLER : *Ibid.*, 1953, vol. 174, pp. 108–120.
10. C. R. FELMLEY, C. E. HARTBOWER, and W. S. PELLINI : *Welding J.*, 1951, vol. 30, pp. 451s–458s.
11. C. F. TIPPER : *J. Iron Steel Inst.*, 1952, vol. 172, pp. 143–148.
12. W. M. BALDWIN, jun.: *Proc. Amer. Soc. Testing Mat.*, 1949, vol. 49, pp. 539–583.
13. " Residual Stress Measurements ": 1952, Cleveland, Ohio, American Society for Metals.
14. R. M. BAKER, R. E. RICKSECKER, and W. M. BALDWIN, jun. : *Trans. Amer. Inst. Min. Met. Eng.*, 1948, vol. 175, pp. 337–354.
15. B. B. HUNDY : *J. Iron Steel Inst.*, 1954, vol. 178, pp. 34–38.
16. A. H. COTTRELL and G. M. LEAK : *Ibid.*, 1952, vol. 172, pp. 301–306.
17. C. A. WERT : *Phys. Rev.*, 1950, vol. 79, pp. 601–605.
18. C. A. WERT : *J. Appl. Phys.*, 1950, vol. 21, pp. 1196–1197.
19. G. B. GREENOUGH : " Progress in Metal Physics," vol. 3, pp. 176–219 : 1952, London, Pergamon Press.
20. A. HAYES and R. S. BURNS : " The Working of Metals," pp. 129–156 : 1937, Cleveland, Ohio, American Society for Metals.
21. T. B. MONTGOMERY : *Iron Steel Eng.*, 1942, vol. 19, April, pp. 90–100.
22. P. W. WRIGHT and B. B. HUNDY : To be published.
23. A. J. K. HONEYMAN : Private communication.

Investigations on Taphole Clays and Taphole Practice

By W. Banks and H. M. Richardson, B.Sc., F.R.I.C.

SYNOPSIS

The types of material used for taphole clays are given and the properties of 12 commercial taphole clays have been determined and are discussed. Investigations on the working of a blast-furnace taphole include the determination of the temperature distribution through the clay in a stopped hole between casts, the effect of coal addition to the clay mixture, and the examination of samples removed from positions very close to the molten iron at cast time. The effect of the extrusion of a plastic-clay column into a laboratory furnace and experiments on the effect of the type of gun used on the length of the hole obtained in practice are described.

It is concluded that (i) a powerful taphole gun is important, (ii) as the temperature along the major part of the hole is low the mixture should have a low drying shrinkage, (iii) reaction between slag and clay is more important than that between molten metal and clay and thus a refractory grog should be used and blowing at the hole discouraged, (iv) coal addition to the taphole mixture facilitates drying between casts and drilling of the hole, but addition of too much coal can result in short and weak holes. 951

IT was agreed by the Blast-Furnace Practice Committee that the tapping-hole practices at different works were so varied that the whole subject should be discussed at a conference, which was held in November, 1948; a questionnaire dealing with taphole practice was circulated, with the result that the Committee now felt that research work on taphole clays should be attempted in co-operation with the British Ceramic Research Association. It was suggested that the work should deal with the clay mixture as (i) a plastic mass and (ii) a refractory resistant to the action of slag and molten iron.

The problem has since been discussed at the 18th and 19th Blast-Furnace Conferences and work has been done both in the laboratory and at various furnaces. This work and discussion is summarized in the present paper.

SOME PROPERTIES OF COMMERCIAL TAPHOLE MIXTURES

Samples of twelve taphole clays were received in the laboratory in the plastic state in sealed tins. They were mainly fireclay–grog mixtures with or without coal additions, but one was a ganister mixture of very low plasticity.

The results of experiments in which certain properties were measured are shown in Tables I and II.

The moisture content was determined by drying the taphole clays at 110° C., and was calculated as the amount of water that had been added to 100 g. of

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Paper IM/C/41/52 of the Blast-Furnace Practice Committee of the Ironmaking Division of the British Iron and Steel Research Association, received 3rd March, 1954. The views expressed are the authors', and are not necessarily endorsed by the Committee.

Mr. Banks is Blast-Furnace Manager of the Clyde Ironworks of Colvilles Ltd., Glasgow, and Mr. Richardson is a member of the Research Staff of the British Ceramic Research Association, Stoke-on-Trent.

Table I

PROPERTIES OF TAPHOLE CLAY MIXTURES

n.d. = Not determined

Clay	Moisture Content, %	Drying Shrinkage, %	Green Strength, lb./sq. in.	Workability*
A	17·6	3·0	81·5	Good
B	16·7	2·0	81·5	Good
C	16·5	3·0	n.d.	Fairly good
D	19·8	4·5	117	Good
E	16·1	3·3	55	Fairly good
F	17·2	3·1	108	Fairly good
G	13·0	2·5	168	Good
H	20·0	2·3	131	Fairly good
I	12·2	1·0	214	Very poor
J	17·2	5·0	254	Good
K	15·8	2·5	127	Fair
L	12·2	2·0	n.d.	Fairly good

* *i.e.*, the ease with which the moistened taphole clay mixture can be moulded into a shape

dry clay–grog mixture. The drying shrinkage was determined by measuring the decrease in length of moulded bars, made from the clays at the moisture content as received, after drying at 110° C. The green strength reported was the transverse strength of dried bars, each value being an average of six determinations.

The firing shrinkage was calculated by measuring the decrease in length of dried test bars after heating in air for 2 hr. at 950° C. and then for a further 2 hr. at 1100° C. The percentage apparent porosity was determined on specimens fired at 1100° C.

Sample *I* was not a fireclay–firebrick mixture, but contained a high percentage of Sheffield ganister. This ganister mixture expanded after firing at 1100° C., and the expansion was equal to the small drying contraction, with the result that the material, wet to fired, was non-contractile at 1100° C., and had a fairly high porosity of 32%. All the other materials contracted after drying and firing at 1100° C., although some mixtures bloated, which caused a reduction in the firing contraction. The effect of the added coal in mixtures *A*, *B*, and *C* was to increase the porosity and to decrease the green strength of the specimens.

The chemical analyses and refractoriness squatting values were obtained by the standard methods, but the workability of each material was estimated from the general behaviour of the clay on being moulded into bars and from the results of extrusion tests on the plastic mixtures. The extrusion test entailed passing the wet clay through a small pug in order to form test samples of 1-in. square section, to which a tension was applied, the amount of elongation of the sample before fracture being measured. This test was only partially successful, because it was found impossible to force some of the mixtures through the pug.

Two types of test to determine the resistance of the taphole clays to attack by blast-furnace slag have been attempted. In both cases a slag of the following chemical analysis was used:

SiO_2, %	FeO, %	Al_2O_3, %	MnO, %	CaO, %	MgO, %	S, %
29·8	0·6	20·7	1·52	39·48	6·81	1·9

In the first test, briquettes (3-in. cubes) were moulded from the taphole clays and a hole 1 in. in diameter and 1 in. deep was drilled into one face of each specimen. The briquettes were fired at 1200° C. The hole was then filled with the slag, and the briquettes and slag were refired to 1200° C. for 2 hr. The test was not successful because at 1200° C. there was practically no reaction between the slag and the brick, but some of the briquettes were bloating and cracking at this temperature. There was a small reaction between the slag and clays *I*, *K*, and *A*, but in the cases of clays *K* and *A* the reaction was very slight. The second attempt was a cone squatting test in which cones were moulded from mixtures of powdered slag and dried powdered taphole clay. Two series of cones containing (i) 20% and (ii) 40% of slag were made and the temperature of initial deformation of the cones was determined.

Firing shrinkages of eight of the taphole clays were determined by a second method, in which the volumes of test specimens were measured before and after

Table II

PROPERTIES OF TAPHOLE CLAY MIXTURES

Clay	Firing Shrinkage, %		Apparent Porosity, %	Refractoriness Squatting Value, ° C.	Chemical Analysis, %								Deformation Temperature for Clay–Slag Cone Squatting Test, ° C.	
	950° C.	1100° C.			SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	$Na_2O + K_2O$	Loss on Ignition	20% Slag	40% Slag
A	0·5	1·2	40·0	1580	48·97	1·22	26·82	2·19	0·31	0·58	1·17	18·52	1310	1260
B	0·4	2·1	38·5	1580	48·62	1·22	27·27	3·12	0·41	0·20	1·41	17·53		
C	0·5	Nil	52·9	1650–1670	39·80	0·92	27·98	3·31	0·90	0·76	2·56	23·90	1350	1340
D	Nil	2·7	24·0	1530	58·67	1·23	22·10	2·87	0·65	0·73	2·71	11·16	1290	1290
E	0·9	3·2	20·5	1410–1435	58·52	1·08	22·48	5·62	0·62	1·43	3·78	6·56	1255	1195
F	+0·9	0·5	35·1	1520–1530	63·80	0·96	21·39	3·19	0·59	0·65	1·45	7·90	1360	1230
G	Nil	2·0	23·0	1580	55·81	1·17	25·15	3·0	0·48	0·90	3·16	10·69	1270	1215
H	Nil	0·66	28·3	1500	62·98	1·42	22·42	4·06	0·80	0·76	2·90	5·47	1260	1170
I	+1·0	+1·0	32·0	1580	83·98	0·50	3·84	3·19	0·30	0·13	0·78	7·57	1400	1160
J	0·5	2·4	30·7	1580–1610	56·16	1·22	22·30	4·69	0·44	0·60	1·72	13·21	1200	1210
K	+0·5	1·0	25·7	1480	58·18	1·12	23·01	5·50	0·44	0·96	1·60	7·94*	1260	1190
L	Nil	2·8	25·2	1530–1580	54·05	1·08	24·03	5·87	0·52	0·90	2·33	11·28	1290	1255

* Including 1·03% SO_3

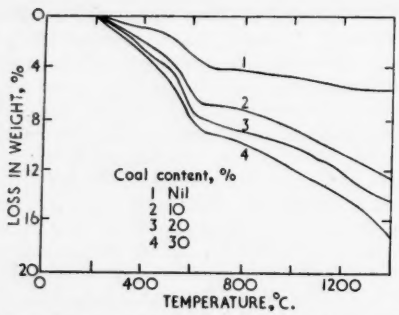


Fig. 1—Effect of heating taphole clay mixture, with and without coal additions, for 2-hr. periods at increasing temperature

heating for 2 hr. at temperatures ranging from 1000° to 1400° C. The specimens were heated in an atmosphere of nitrogen in an effort to determine changes in volume that may occur under conditions approaching those which prevail in the taphole, where there is no free access of oxygen. Under these conditions the coal should not burn, but the distillation of volatile matter should take place. The results are given in Table III. Note that at 1000° C. all the taphole clays decreased in volume, but that at 1100–1200° C. the impure clays *E* and *K*, of low refractoriness, began to bloat. Other taphole clays showed expansile tendencies at higher temperatures.

The volume changes of clays *E* and *K* could not be measured at 1300° and 1400° C. because they began to melt and deform at these temperatures in the nitrogen atmosphere.

The results obtained on examining the properties for the 12 taphole clays emphasized the variable nature of the materials used at the different plants. The refractoriness squatting values varied from 1410–1435° C. for clay *E* to 1660° C. for clay *C*. The chemical analyses also contained significant differences even if the ganister mixture *I* is not considered; the values for the alkali-oxide and iron-oxide contents showed marked differences and the silica content varied from 63·8 to 39·8%.

An important property, the linear drying shrinkage, varied from 1·0 to 5·0% and the firing shrinkage results were also different. The changes in volume, measured after heating samples of the taphole clays in nitrogen at temperatures of up to 1400° C., tended to suggest that the coal additions made in mixtures *A*, *D*, *F*, and *G* might have reduced the firing shrinkages at certain stages during the heat treatment.

EFFECT OF COAL ADDITIONS TO CLAY–GROG MIXTURES

Since coal is widely incorporated in taphole clays, it was decided to add coal to a clay–grog mixture to determine its effect on the properties of the mixture. A fresh sample of taphole clay *H* was obtained and additions of 10, 20, and 30% of coal were made, calculated on the weight of dry materials in the plastic mixture. The analysis of the Shropshire coal which had been crushed to pass a $\frac{1}{8}$-in. mesh sieve was:

Moisture, %	5·8	Fixed carbon, %	42·4
Volatile matter, %	30·9	Sulphur, %	1·05
Ash, %	20·9	Calorific value, B.Th.U./lb.	10,260

Specimens, in the form of bars 4 in. × 1 in. × $\frac{1}{2}$ in., were moulded from the taphole clay and from the

Table III
VOLUME CHANGES ON FIRING CLAY MIXTURE IN NITROGEN
+ = Expansion − = Contraction

Clay	Volume Change, %, after Heat Treatment at					Remarks
	1000° C.	1100° C.	1200° C.	1300° C.	1400° C.	
A	−4·29	− 7·45	n.d.	− 5·84	− 4·19	Coal
D	−6·79	− 8·7	− 3·72	− 3·46	+ 9·64	Coal
E	−3·16	+15·57	+78·36	n.d.	n.d.	Impure clay, no coal
F	−0·76	+ 0·32	− 0·70	− 1·70	− 8·25	Coal
G	−3·49	− 2·81	+ 0·36	− 5·42	− 1·27	Coal
H	−0·65	− 4·78	− 8·33	− 5·98	− 1·76	No coal
J	−5·69	− 6·9	−13·36	−14·87	−13·37	No coal
K	−3·29	− 5·45	+10·39	n.d.	n.d.	Impure clay, no coal

Table IV
DRYING AND FIRING SHRINKAGES OF CLAY–GROG–COAL MIXTURES
+ = Expansion − = Contraction

Coal Content in Mixture, %	Linear Drying Shrinkage, %	Volume Change, %, on Heating Separate Specimens in Nitrogen to				
		600° C.	800° C.	1000° C.	1200° C.	1400° C.
0	3·0	...	+0·37	−0·72	−3·85	− 8·92
10	2·7	+0·98	+0·11	−1·08	−5·90	− 9·87
20	2·0	+1·38	+0·30	−1·32	−5·66	−12·57
30	1·7	+0·67	+0·58	−1·48	−5·60	−12·98

mixtures of the coal and clay. The drying shrinkage of each bar was measured and then the specimens were heated in a nitrogen atmosphere at temperatures of up to 1400° C. After each heat treatment the loss in weight, change in volume, and percentage apparent porosity of the specimens were determined. Some specimens were heated directly to one specified temperature that was maintained for 2 hr., as shown in Table IV, whereas other specimens were heated successively for 2-hr. periods at increasing temperatures, as shown in Fig. 1. The properties of the heated mixtures are collected in Fig. 2.

The volume of each specimen remained almost constant after heating to 700° or 800° C.; there was no marked volume change caused by the coal addition in this temperature range. Above 900° C. the bars decreased in volume and contraction increased with the addition of coal. With these coal–clay mixtures no bloating occurred. The coal addition increased the porosity of the heated bars, the porosity of each mixture increasing to a maximum at 1000° C., whilst at higher temperatures vitrification took place. The rate of loss in weight increased between 550° and 600° C., which coincided with the decomposition of the clay molecule and, of course, the specimens containing coal showed an additional loss in weight. Although there was a very small increase in volume with the 30% coal sample below 600° C., this increase did not counteract the drying shrinkage.

After these laboratory tests the opportunity arose to test the effect of adding coal to clay *H* and observing the behaviour of the mixtures at Furnace 1 of the Shelton Iron and Steel Co. The furnace had made 674,011 tons of basic iron, the average analysis of which was as follows:

Si, %	P, %	S, %	Mn, %
0·75	1·19	0·106	1·82

The furnace hearth diameter was 17 ft., the hearth wall thickness was 3 ft. 4½ in., and the taphole was drilled at an angle of 29°. During the experiments the average slag analysis was:

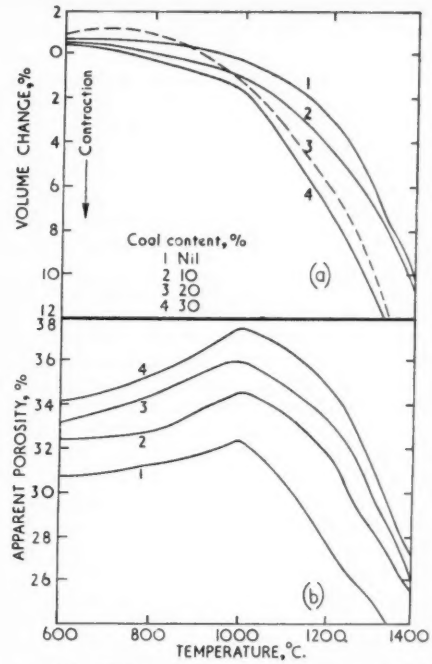


Fig. 2 — (*a*) Volume-change/temperature and (*b*) apparent-porosity/temperature curves for taphole clay mixture with and without coal additions

SiO_2, %	CaO, %	Al_2O_3, %	MgO, %	S, %	FeO, %	MnO, %
30·8	37·9	17·3	9·3	2·31	0·6	2·3

The clay is supplied in the plastic condition to the works, equal parts of clay and grog having been mixed in a tempering pan, wetted, and pugged. It may be stored for a considerable time before being used and it gives satisfactory service at the Shelton furnaces. The clay mixture is forced into the taphole with an electrically operated piston-type gun of

Table V

EFFECT OF COAL ADDITIONS TO TAPHOLE CLAY *H* AT SHELTON No. 1 FURNACE

	H	B	C	D	E	H
Composition of mixture, %						
Clay	50	45	45	50	40	50
Grog	50	45	45	40	40	50
Coal	0	10*	10	10	20	0
No. of stops per mixture	48	44	61	137	60	60
Cast time, min.	13·4±6·44	13·5±4·45	18·2±8·17	20·4±7·67	20·3±8·2	21·3
Pig per cast, tons	80·9±10·3	82·0±12·9	79·4±10·9	80·7±10·3	81·4±11·7	77·3
Length of hole (no. of stops per keeper in brackets)						
Average of total	4 ft. 5 in.±11·0 in.	4 ft. 6 in.±7·7 in.	4 ft. 8 in.±6·7 in.	4 ft. 5 in.±8·0 in.	4 ft. 0 in.±8·4 in.	4 ft. 6 in.
Average for each keeper:						
No. 1	4 ft. 6 in. (12)	4 ft. 10 in. (11)	4 ft. 8 in. (18)	4 ft. 6 in. (4)	4 ft. 2 in. (16)	4 ft. 8 in. (16)
No. 2	4 ft. 0 in. (14)	3 ft. 6 in. (4)	4 ft. 6 in. (13)	4 ft. 0 in. (39)	3 ft. 5 in. (16)	4 ft. 0 in. (17)
No. 3	4 ft. 8 in. (12)	4 ft. 9 in. (12)	4 ft. 9 in. (19)	4 ft. 8 in. (38)	4 ft. 4 in. (14)	4 ft. 7 in. (19)
No. 4†	4 ft. 11 in. (4)	4 ft. 8 in. (6)	5 ft. 0 in. (3)	4 ft. 7 in. (12)	3 ft. 9 in. (9)	4 ft. 8 in. (8)
No. 5‡	...	4 ft. 2 in. (6)	4 ft. 9 in. (4)	4 ft. 4 in. (7)	4 ft. 3 in. (5)	...
Roughing slag, tons	6·1	4·0	5·9	6·1	6·1	5·8
Column of clay used per stop, cu. ft.	3·27	3·47	3·27	3·14	3·35	3·12

* Poor quality † Part time ‡ Others

9 cu. ft. capacity, but normally only 3–4 cu. ft. of clay is used after each cast because an attempt is made to stop the hole with a minimum amount of clay; from experience, and noting the length of the hole and the rate of flow of iron from the furnace, the keeper estimates the amount of clay to be used. An air-operated, 3-in. dia. drill is used to make the hole. No rack is used to ensure that the hole is drilled at exactly the same angle each time, but the furnace is cast dry and the hole is stopped up finally against full blast pressure, the blast being increased as the clay enters the hole.

Several batches of the taphole mixture with coal additions were obtained from time to time from the usual supplier. Table V records the mixture used at the furnace and the facts noted during the experiments. As many data as possible were obtained with a view to assessing the performance of each clay.

It is assumed that the length of the hole is the most important property required; a 10% coal addition appeared to have very little effect, but the addition of 20% of coal produced a shorter hole. Qualities other than length of hole are of interest but are not easily measured. The keepers indicated that the coal addition made the clay easier to drill and easier to dry out between casts. Their general opinion was that at Shelton the 10% addition maintained the hole in about the same condition, but that a 20% addition of coal was excessive because at times the clay gave way and the 'face' of the hole had to be made up quite often with normal clay.

EXAMINATION OF SAMPLES REMOVED FROM FURNACE TAPHOLES AT CASTING TIME

Numerous samples have been taken from various tapholes at casting time. In the first series of experiments samples of the drillings removed by the keeper were tested for carbon and water content as well as loss on ignition, and the same samples were examined by X-ray powder methods. These results indicated that the carbon content and the loss on ignition of the drillings were high, and the X-ray powder photographs proved that undecomposed clay—the hydrated clay molecule—was still present in samples taken 4 ft. 6 in. down a taphole. It was realized that the clay mixture along that part of the hole normally drilled by the keeper was practically unfired and that samples must be obtained from positions much closer to the molten metal. Such samples were obtained from furnaces at Shelton and at Clyde Ironworks by the use of a hollow mild-steel bit, 6 in. long and with $\frac{7}{8}$ in. internal dia., screwed to a 12-ft. long, $1\frac{1}{8}$-in. dia. metal bar. This core sampler was used after the hole had been partially drilled in the normal manner, the sample being driven into the hole by means of a sledge-hammer and a sample of used clay being collected in the hollow removable bit. The sample sometimes consisted of powdered clay but cylindrical samples of fired clay, or mixtures of fired clay and iron, were also obtained. Occasionally the furnace cast as the sampler was removed from the hole but often oxygen had to be used.

Shelton Samples

Nineteen samples were taken with the aid of the core sampler and a number of these samples were examined by X-ray powder methods. Some results are shown in Table VI.

Samples Obtained at Clyde Ironworks

The sampling method used at Shelton was also used at each of the three furnaces at Clyde Ironworks. The

Table VI

RESULTS OF EXAMINATION OF SHELTON SAMPLES REMOVED AT CASTING TIME

Sample No.	Length Drilled	Penetration of Sampler, in.	Furnace Finally Cast by	Description of Sample	Crystals Identified by X-ray Method
1	5 ft. 6 in.	4	Sampler	Solid cylinder $\frac{1}{2}$ in. long was removed from hot end of sampler. This consisted of fired clay and globules of iron. Remainder of sample consisted of powdered material	0–$\frac{1}{2}$ in. from surface: mullite, quartz, cristobalite, iron, iron phosphide $\frac{1}{2}$–1 in. from surface: mullite, quartz, cristobalite with small amount of iron 2–3 in. from surface: mullite, quartz, cristobalite
2	4 ft. 10 in.	$3\frac{1}{2}$	Oxygen; although some molten iron followed removal of sampler	Iron and clay had solidified at hot end of sampler and some iron had penetrated with the powdered clay to cooler end	Surface of specimen contained mullite, quartz, cristobalite, iron, and cementite
3	4 ft. 6 in.	2	Sampler	Iron and clay were mixed at front of sampler but powdered clay filled remainder of tube	Specimen surface consisted of mullite, quartz, cristobalite, and small amount of iron cordierite
4	5 ft. 6 in.	3	Oxygen	Iron had penetrated to cooler portion of tube and had formed thin 'shell' around some of the clay which was present as powder at cooler end	Mullite, cristobalite, quartz, iron, iron phosphide, and iron cordierite

Table VII
RESULTS OF EXAMINATION OF CLYDE SAMPLES REMOVED AT CASTING TIME

Sample No.	Distance Drilled	Penetration of Sampler, in.	Furnace Cast by	Description of Sample	Crystals Identified by X-ray Method
5 (Furnace 3)	4 ft. 0 in.	4	Sampler	Mixture of iron and clay	Surface of sample contained iron, quartz, cementite, iron phosphide, but cooler end contained quartz, mullite, and kaolinite
6 (Furnace 1)	2 ft. 6 in.	6 End of sampling tube melted but 4½-in. length of sample was obtained	Sampler	*A* Solid material at hot surface difficult to remove from sampler	Iron, quartz, and mullite
				B Cylindrical plug of iron and fired clay, ½ in. behind hot surface	Quartz, mullite, and small amount of iron
				C Powdered material close to metal about 2 in. behind hot surface	Quartz, mullite, kaolinite
				D Powder which filled about 2½ in. of the cooler end of the sampling tube	Quartz, mullite, kaolinite, siderite
7 (Furnace 1)	2 ft. 0 in.	5	Hole began to bleed when being widened by drill	*A* Powdered clay from hot end of sampler	
				B Wet clay plug within 3 in. of molten metal	Quartz, siderite, kaolinite, small amount of mullite
8 (Furnace 1)	1 ft. 6 in.	5	Sampler	*C* Powdered material from cooler end of sampler	Quartz, mullite, iron
				B Solid plug of iron and fired clay about 1½ in. long from hot end of sampler	Quartz, iron cementite, iron phosphide
				A Surface of this solid plug	Quartz, mullite, iron

method of casting these furnaces was essentially the same as at Shelton but differed in that (i) a rack was used to ensure that the hole was drilled out at the same angle, and (ii) clay was forced into the hole until the gun stalled or until the gun barrel was empty. Samples were obtained before 32 casts; in most cases more than one clay sample was taken at each cast. It was necessary to use the hollow sampler after a hole had been drilled for only a short distance and to repeat the process as the hole was lengthened because in a number of cases the sampler was readily driven right through to the molten metal. The sampler was often lost if the hole was drilled until red-hot clay was reached. It was also found that sometimes the hole was 'wet'; plastic clay remained 4 or 5 ft. up the taphole. When this condition prevailed the sampler could often not be driven through into the molten metal and it is possible that metal had solidified within 2 or 3 in. of the plastic clay.

The results of the analyses of some of the samples are given in Tables VII and VIII.

Discussion

The results obtained at the Clyde Ironworks confirmed the findings at Shelton. There was very little reaction between the clay mixture and the molten metal. The small amount of iron cordierite identified in samples 3 and 4 at Shelton did indicate that a small amount of iron had oxidized to ferrous oxide which had then reacted with the clay to form this mineral, but in general the samples contained quartz, mullite, and cristobalite which are the crystals that form the fired clay.

No lime minerals were identified in the samples and, therefore, there was no slag attack on the clay at the iron/clay interface. This observation is confirmed by the chemical-analysis figures in Table VIII, there being no marked increase in the lime content towards the hot end of the hole.

The mineral kaolinite ($Al_2O_3.2SiO_2.2H_2O$) was identified in samples which were taken only 2 or 3 in. from the molten metal. This indicates that the clay is unfired along the major length of the hole and any shrinkage will be drying and not firing shrinkage.

The minerals cementite and iron phosphide must be associated with the metal and they could not be formed by the interaction of the clay mixture with the metal or slag.

A chemical analysis of the plastic clay taken from the clay gun was:

SiO_2, %	Al_2O_3, %	CaO	Fe, %	(Fe_2O_3, %)	MgO, %	H_2O, %
44·80	24·00	trace	2·16	(4·52)	1·42	12·0

Loss on ignition of dry sample was 11·88%, which consisted of 9·15% H_2O and 2·73% C. The Al_2O_3/SiO_2 ratio of this raw plastic clay was 0·536. This ratio of the samples in Table VIII increased to 0·69 as the hot end of the hole was approached. The fired material when mixed with a high percentage of

Table VIII
CHEMICAL ANALYSES OF SOME SAMPLES

Sample No.	SiO_2, %	TiO_2, %	Al_2O_3, %	Fe_2O_3, %	CaO, %	MgO, %	K_2O, %	Na_2O, %	MnO, %	SO_3, %	Loss on Ignition, %	Al_2O_3/SiO_2 Ratio
7*B*	51·78	1·14	27·56	3·87	0·29	0·66	1·38	0·06	...	...	12·97	0·53
8*C*	49·27	1·02	28·27	20·55	0·35	0·56	0·92	0·04	0·05	0·08	...	0·57
8*B*	21·84	0·60	14·96	85·78	0·30	0·40	0·52	0·01	0·54	0·04	...	0·685
6*D*	53·09	1·18	28·89	3·03	0·40	0·62	1·50	0·10	0·01	0·14	11·13	0·545
6*B*	23·96	0·78	15·80	78·20	0·34	0·56	0·90	0·08	1·34	0·08	...	0·659
6*A*	17·66	0·78	12·32	93·38	0·32	0·44	0·60	0·02	1·62	0·05	...	0·698

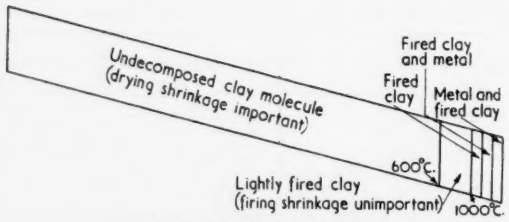


Fig. 3—A 4-ft. long taphole

metallic iron, calculated in the analysis as ferric oxide, showed a high Al_2O_3/SiO_2 ratio. This indicates that the silica content of the mixture had decreased, possibly as a result of reduction to silicon which had dissolved in the metal. This was the only indication of direct action of the metal with the clay mixture.

TEMPERATURE DISTRIBUTION AND CONDITION OF MIXTURE ALONG CLOSED TAPHOLE

At each of the Shelton furnaces temperature measurements along the taphole plug were taken by the insertion of a thermocouple in a sheath, and the following observations were made.

If the depth to which the thermocouple was placed approached the taphole length at the following cast then the temperature recorded increased fairly rapidly towards casting time, but did not exceed 800° C. during the experiments.

The experiments confirmed the results obtained from the analyses of the clay samples, *viz.*, that the clay remained undecomposed, showing that the temperature had not exceeded 600° C. along the major portion of the taphole plug.

From these results and those from the examination of samples removed at casting time the conditions obtaining along the taphole at casting time can be shown diagrammatically.

Figure 3 illustrates a taphole 4 ft. long. From the outside the first 3 ft. 6 in. has not been heated above 600° C. This is shown by the fact that undecomposed clay, kaolinite, is present in the drilled samples. At the inside end of the plug the first inch is composed of molten metal and hard fired clay mixture, the next inch most probably being fired clay mixture penetrated by globules of molten iron. Between this part and the 3 ft. 6 in. section of undecomposed clay there is a section which has been only lightly fired to about 1000° C. with no firing shrinkage.

EXTRUSION OF PLASTIC CLAY INTO A LABORATORY FURNACE AND THE EFFECT OF TYPE OF GUN USED ON LENGTH OF HOLE

Laboratory Experiments

A taphole clay mixture was extruded and forced through a hole in the door of a laboratory furnace. To perform this experiment successfully the hole in the brick door had to be made slightly larger than the 1-in. dia. die of the extrusion machine. The extruded clay passed into the furnace without apparent bloating and certainly without exploding. The furnace was maintained successively at 900°, 1000°, and 1400° C. The percentage apparent porosity of the column which was quickly removed from the furnace was 39·2 at 900° C., 42·2 at 1000° C., and 34·2 at 1400° C., whilst the porosity of the extruded clay after careful drying and firing to 1000° C. was 36·2%. The results indicated that there was some increase in porosity caused by the rapid evolution of steam from the mixture, but at 1400° C. the mixture had started to vitrify. In attempting to repeat these experiments with a column of clay 2 in. in diameter the clay bloated in the furnace door so that the extrusion machine was not strong enough to force the clay into the furnace. This later result indicated that a strong gun was necessary to keep the clay column moving into the furnace.

Plant Experiments

The results obtained at Clyde Ironworks on three similar furnaces, using the same kind of clay but with different types of taphole guns, are given below.

Operational Details

The same casting procedure is followed across all three furnaces. Each furnace casts five times per day to a regular schedule and as there is usually sufficient ladle capacity, it happens only rarely that that they are ' not dry ' at cast.

The taphole is drilled at a constant angle of 25° by means of a compressed-air drill resting on a stand, drilling commencing about 1 hr. before cast. The distance drilled is measured at intervals, the keeper using his own judgment as to how far he can drill with safety. When drilling ceases, a final measurement is taken before the hole is pierced with oxygen. The distance drilled is taken as the taphole length and recorded as such, the length of lancing tube used also being recorded, this being usually 15–30 ft.

Hard blowing at the taphole is not encouraged. It is usual to stop the hole on reduced wind, the wind being increased to full when the charge is completed. Once the complete charge is in, only a minute or two elapses before the gun is withdrawn.

Furnace 3

Type of gun	Electric chain rammer of 9 cu. ft. capacity
Hearth dia., ft.	20
No. of tuyeres	12
Thickness of hearth wall	3 ft. 4½ in.
Wind vol., cu. ft./min.	38,000–40,000
Tuyere pressure, lb./sq. in.	14–16
Average wt. per cast, tons	124

This furnace was blown in on 12th January, 1948, and has now produced 800,000 tons.

The taphole is below and between tuyeres 1 and 12, these tuyeres having been kept open throughout the campaign. From blowing-in until early in 1949 these two tuyeres were 15 in. × 6 in., being then changed to 18 in. × 4½ in. and remaining so ever since.

Throughout the campaign the taphole has been very consistent and has given very little trouble, the length varying between 4 and 5 ft. No trouble has been experienced in keeping a hole of such length during normal operation. At all times it has been the policy to give the taphole a full charge of clay (9 cu. ft.) and at times a double charge has been given. There has been no attempt to see if the taphole length could be maintained with less than 9 cu. ft. per cast.

Figure 4*a* shows the monthly average length from

January, 1950, to June, 1951, the average length being 4 ft. 1 in. for 1950, and 4 ft. 10 in. for the first 6 months of 1951.

Furnace 1

Type of gun	Electric twin-screw
Hearth dia.	18 ft. 3 in.
No. of tuyeres	10
Thickness of hearth wall	3 ft. 4½ in.
Wind vol., cu. ft./min.	32,000–34,000
Tuyere pressure, lb./sq. in.	13–16
Average wt. per cast, tons	100

Furnace 1 went into operation in April, 1949, after its first reline. At the end of its first campaign, during which it produced 1,512,000 tons, it was operating with a short taphole, the length averaging about 2 ft. 0 in. The twin screw gun was in constant operation throughout and from the then operator's opinion the taphole was not good.

The taphole is under tuyere 1 and since the beginning of the present campaign this tuyere size has been 18 in. × 4½ in.

Although great attention was given to maintaining the taphole a reasonable length could not be attained. Short holes were common and various expedients were tried. On occasion the taphole tuyere was plugged for several days, which resulted in some improvement, but immediately the tuyere was opened the hole shortened. Stopping the hole on very easy wind also effected some improvement but as this resulted in slowing up the furnaces it was not very popular. However, it was decided that the best results were obtained using this method and so it has been continued. The taphole tuyere is now open all the time and the hole is usually stopped with the wind at 3–4 lb./sq. in.

Throughout the campaign it has been apparent that the taphole condition arose through the inability of the gun to push in sufficient clay, the average charge per cast being about 3–4 cu. ft. Only occasionally will the gun push in more than this amount, but when it does a longer hole results, as one would expect.

Figure 4*b* illustrates the average monthly length throughout the campaign, the present total output now being 425,000 tons.

Furnace 2

Type of gun	(1) Electric twin-screw (2) Electric piston gun of 12 cu. ft. capacity
Hearth dia.	18 ft. 3 in.
No. of tuyeres	10
Thickness of hearth wall	3 ft. 4½ in.
Wind vol., cu. ft./min.	
Normal operation	32,000–34,000
High top pressure	37,000–38,000
Tuyere pressure, lb./sq. in.	
Normal operation	13–16
High top pressure	18–21
Average wt. per cast, tons	100

Throughout the first campaign, during which 1,566,000 tons was made, this furnace was equipped with an electric twin-screw clay gun and, as at Furnace 1, the taphole was hardly ever long. During the last few months of the campaign it was in fact very short and gave more than a little trouble.

When it was decided to convert this furnace for high top pressure operation the problem of improving the

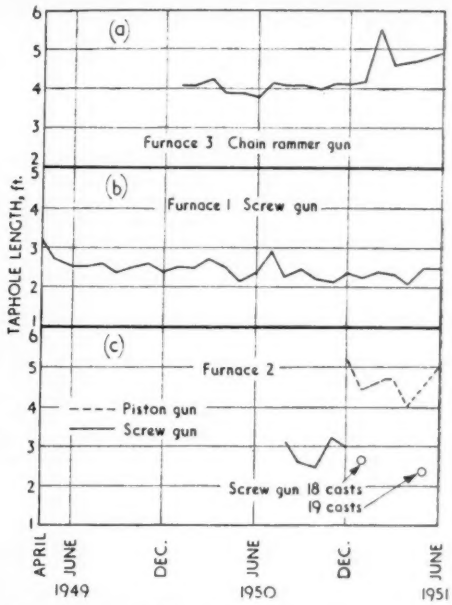


Fig. 4—Average taphole lengths for the three furnaces

taphole performance became very urgent. From experience with the screw gun on the new Furnace 1 we considered it was not powerful enough to satisfy the requirements of a high-pressure furnace and so it was decided to install a piston-type gun of 12 cu. ft. capacity. However, this new gun could not be ready in time for the blow-in and so the furnace went into operation at the end of July, 1950, equipped with the old screw gun.

The taphole at this furnace is below tuyere 1 and as at Furnace 1 the tuyere size is 18 in. × 4½ in.

As at Furnace 1 the taphole length was disappointing despite every effort and for the same reason. We could not get sufficient clay into the hole. After a little clay had been fed through the gun the resistance increased rapidly, causing the motor to trip out on overload.

The screw gun was in constant use from blowing-in until 21st December and over this period the average taphole length was 2 ft. 11 in.

The piston gun went into operation on 21st December and for 3 or 4 days both guns were in use until everyone was familiar with the new gun. During this short period the piston gun gave us a much longer hole. With the piston gun in constant use the hole doubled in length and as some very wet holes were experienced the clay charge had to be reduced.

Early in January the piston gun was replaced by the screw gun for 4 days. For the 6 days before the screw gun was used the average taphole length was 4 ft. 3 in. With the screw gun the average length dropped to 2 ft. 10 in., increasing to 4 ft. 6 in. when the piston gun was again put into service.

In May the screw gun was again used for 4 days with the same result. The taphole shortened from 4 ft. 6 in. to 2 ft. 6 in., but the length was regained when the piston gun went into operation (*see* Fig. 4*c*).

Table IX
COMPARISON OF TAPHOLE LENGTHS

Furnace	Type of Gun	Period	Average Taphole Length	Percentage of Casts with Taphole Length less than:		
				1 ft.	2 ft.	2 ft. 8 in.
1	Twin-screw	April 1949–June 1951	2 ft. 6 in.	1·3	16·4	57·2
2	Twin-screw	July 1950–Dec. 1950	2 ft. 11 in.	1·4	8·5	36·0
2	Piston	Dec. 1950–June 1951	4 ft. 9 in.	0·12	0·6	2·1
3	Chain rammer	Jan. 1950–June 1951	4 ft. 4 in.	Nil	0·35	3·0

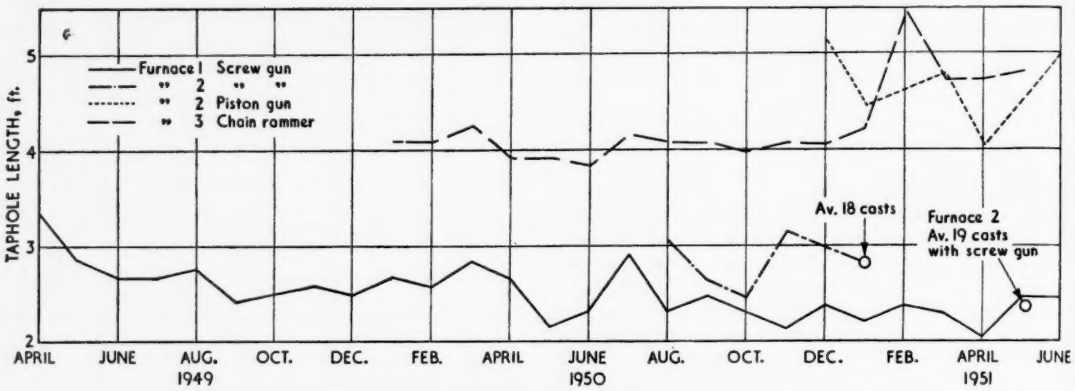


Fig. 5—Comparison of average taphole lengths

Since May the piston gun has been used exclusively, the taphole length being about 5 ft.

A comparison of the results can be seen in Table IX and Fig. 5. In Table IX the length of 2 ft. 8 in. has been taken as a standard, as this is the average length of Furnace 1 taphole during the first 9 months of the present campaign.

Furnace 1 taphole has tended to shorten whereas Furnace 3 taphole has been maintained, as shown by the following:

Year	Percentage of Casts with Taphole Length less than: 1 ft.	2 ft.	2 ft. 8 in.
Furnace 1			
1949	1·1	9·7	51·0
1950	1·5	20·4	58·0
1951	1·4	18·6	64·0
Furnace 3			
1950	Nil	0·46	3·71
1951	Nil	0·11	1·60

The taphole clay analyses were as follows:

Date	SiO_2, %	Al_2O_3, %	CaO, %	Fe, %	MgO, %	Loss on Ignition, %
22.7.49	44·08	34·28	0·40	0·92	0·54	19·35
12.8.49	48·82	27·51	0·40	1·52	0·36	20·23
24.2.50	47·60	32·16	0·24	0·80	0·20	18·46
17.9.50	48·06	33·49	1·12	0·92	0·46	14·62
24.4.51	51·20	31·25	0·28	3·18	0·57	12·65

CONCLUSIONS

(1) Whilst the chemical composition of the taphole clay mixture may vary at different works it is important that the drying shrinkage should be low.

(2) The use of a powerful taphole gun is essential.

(3) The optimum percentage of fireclay in a fireclay–grog clay or in a ganister–clay mixture will depend upon the plasticity and particle size of the particular clay, and upon the strength of the taphole gun. A strong gun may force a mixture of low clay content into the hole but more clay will be needed when a weaker gun is used.

(4) The addition of coal tends to facilitate drying of the mixture between casts and the drilling of the hole because it will tend to increase the porosity of a dry or fired clay–grog mixture. (If too much coal is used the resultant mixture will be short and a weak hole will result.)

(5) Although no marked chemical attack between molten metal and the taphole mixtures was observed, slag will react with fireclay and grog. To minimize this slag attack it is important to have only a small volume of roughing slag and to minimize blowing at the hole. To resist this slag attack the mixture should contain a refractory grog.

Acknowledgments

For permission to publish the work done by the British Ceramic Research Association, the authors wish to thank Dr. A. T. Green, O.B.E., Director of the British Ceramic Research Association. The authors wish to acknowledge the facilities granted by the managements of Colvilles Limited and of the Shelton Iron, Steel, and Coal Company for carrying out the trials. They also wish to thank members of the staff at the plants concerned for their assistance during the trials.

DISCUSSION ON PAPERS

DISCUSSION AT MEETINGS · WRITTEN CONTRIBUTIONS

THE EIGHTY-FIFTH ANNUAL GENERAL MEETING OF THE IRON AND STEEL INSTITUTE was held in London on Wednesday and Thursday, 26th and 27th May, 1954, at the Royal Institution, Albemarle Street, W.1, and at the Offices of the Institute, 4 Grosvenor Gardens, S.W.1. Mr. JAMES MITCHELL, C.B.E., the Retiring President, was in the Chair at the beginning of the Meeting, his place being later taken by the Hon. R. G. LYTTELTON, the new President.

Sessions were held at 9.45 A.M. and 2.30 P.M. on the Wednesday and at 10 A.M. and 2 P.M. on the Thursday.

The Report of the Meeting is published on pp. 105–108.

Discussion on the Paper—

SOAKING-PIT PRACTICE AT THE NORMANBY PARK STEELWORKS OF JOHN LYSAGHT LTD.*

By A. H. Norris

Mr. **A. H. Norris** (John Lysaght's Scunthorpe Works Ltd.) presented the paper.

Mr. **S. Thomson** (Colvilles Ltd.): I should like to congratulate the author upon the paper and the management on their enterprise in rebuilding their plant. It is stated that the works has a capacity of 10,500 tons/week on the basis of 16 shifts, and that the pit capacity of 800 tons is fully adequate to meet mill requirements, even on the basis of 25% cold metal. Figure 5 shows that there is an increasing output (and naturally a decreasing fuel consumption) with hot material up to the maximum capacity of 18 ingots per cell. The fact that cold steel takes 10–13 hr. to heat, compared with 3–4 hr. for hot steel, is a definite disadvantage with a recuperative pit compared with a regenerative pit; has any attempt been made to determine the best loading of the furnace for cold material?

Figure 6 shows the relationship between track time and heating time, and there is little doubt that the excellent results in fuel consumption and output are largely due to the track times.

The author quotes a figure of 10–11 therms/ton for hot material from charge to draw. Naturally, this figure does not include periods when the pit is empty or when pits are ready for a mill which cannot be drawn. What was the fuel consumption in therms/ton for the complete week, from gas-in on Sunday morning to gas-off on Saturday morning? That would give the true overall operating cost in terms of fuel. The figures quoted for fuel consumption charge-to-draw show a continuous record of improvement up to May, 1953; has this progress been maintained, and what is the present position in regard to fuel consumption?

The bottom brickwork is renewed yearly and the breeze bottom lasts 12–14 working days with a breeze consumption of about 0·5% of the steel heated. This means, in effect, almost an addition of 10% in fuel consumption. What is the author's opinion of the advantage of this type of bottom compared with a crushed dolomite bottom?

The waste-gas temperatures to the recuperator were 900–1000° C. on entering and 400–450° C. on leaving, but the recuperators are close to the furnace, and it would be assumed that the loss would be less than 300° C. Is there any question of cold air being bled into the system?

During the 3 years these pits have been in operation, has the author found any falling-off in efficiency due to infiltration? What are the maintenance costs?

Generally speaking, there must always be a fairly large percentage of cold material, owing to the difference in working shifts in the melting shop and the mills. Since recuperative pits are slow heaters of cold material, as the author has shown, has any consideration been given to the possibility of preheating cold material and thereby increasing the undoubted efficiency of the recuperative pits on hot material?

Mr. **W. Ernest** (United Steel Companies, Ltd.) on behalf of Mr. **J. A. Chapman** (Steel, Peech and Tozer) and himself: Since very little about the operation of modern soaking pits from the operators' standpoint has

* *J. Iron Steel Inst.*, 1953, vol. 175, Dec., pp. 353–359.

been published in the U.K., the following operating data, from a battery of soaking pits of similar design, may be of interest.

These pits, installed at the works of Steel, Peech and Tozer in 1953, are 22 ft. 6 in. long × 7 ft. 3 in. wide and are rated to hold 16 4-ton ingots. The fuel used is coke-oven gas or oil, and the use of these fuels of high calorific value has brought its own problems, especially in regard to control of flame and temperature, if damage to ingots and refractories is to be avoided.

The combined coke-oven-gas and oil burner used consists of a series of concentrically arranged tubes made of heat-resisting steel and is introduced into the hot-air main which surrounds it. The burner tip terminates about 2 ft. behind the pit end-wall. Combustion begins in a circular brick port which in the original design diverged conically from a throat dia. of 21 in. The design maximum input rating was 35,000 cu. ft. of coke-oven gas or its equivalent in heavy fuel oil per hr.

With the divergent port there was a tendency for ingot tops to overheat and the lid showed signs of damage at a position roughly corresponding to the impact of the diverging flame. By altering the port design to a parallel tunnel of 21 in. dia., this trouble was overcome. At the same time the refractory in the lid was changed from firebrick to semi-silica, which has stood up very well to the fiercer type of flame resulting from high-calorific-value fuels.

We agree that the optimum maximum heat input to the pit is important. This was investigated very carefully and it was found to be beneficial to restrict the maximum thermal input without detriment to overall heating rates, since, although the rate of temperature rise of the pit was slightly reduced, a shorter soaking period was found to be adequate. The pits are now operated with a controlled maximum input of 24,000 cu. ft. of coke-oven gas or 75 gal. of oil per hr., and it is found that the pit is ready for drawing when the fuel input has dropped to 25% of this maximum. On two further pits about to be installed the control range of the instruments is to be reduced in line with the experience gained, and to obtain better control at low flows.

Owing to the location of these pits in the shop, and also to their ability to heat cold ingots rather more uniformly and more rapidly than the old existing pits, the percentage of cold charges to these pits is very high. Over a recent period of several months the relevant performance figures are:

Average output per pit week	769 tons
Percentage of cold ingots	62·5%
Fuel consumption	15·5 therms/ton (including lighting-up and standby losses)

On individual test heats of 16 4-ton cold ingots, charged-to-ready fuel consumptions range between 13 and 15·5 therms/ton, the corresponding charged-to-rolled fuel consumption being 13·6–17 therms/ton. For oil these figures are slightly higher, since it is necessary to operate with more excess air to get complete combustion.*

The operating control temperatures used by the author seem to be rather lower than is customary. Lower pit-control temperatures are obviously beneficial in reducing scale formation and increasing refractory life, but they imply the provision of additional heating capacity and capital cost.

In regard to the refractory life of the side walls, the author manages to keep his ingots standing on their bottoms. This desirable practice is possible only with top-poured ingots; with uphill-cast ingots it is essential that they should lean against the side. For this reason the provision of a ramp or over-rail against which the ingots can lean is beneficial, since this can be replaced without replacing the whole wall; it also keeps the charger grips further from the pit wall and so makes damage by the charging crane less likely.

The author makes a passing reference to oxidation losses; his views on overall yields obtained from ingots heated in the new soaking pits, compared with previous practice, would be welcome. This is very important, since an increase in yield of a fraction of 1% would go far towards repaying the high capital cost of soaking pits.

Mr. **R. Slade** (Steel Company of Wales Ltd.): Having had 3 years experience of operating 20 modern pits at Margam, I read this paper with great interest. We heat, in our 20 soaking pits, 33,000 tons of steel per week at about 8½ therms/ton. If the cold stock is limited to about 2500 tons at the start of a week, there may be about 1000 idle pit hr., which means that the capacity of the 20 pits is about 45,000 tons. With equal or better track times fuel consumption would be reduced to about 6 therms/ton.

In his pits the author makes very little slag and uses only an ordinary firebrick for underpinning his linings, whereas he has sometimes to use a poker or oxygen lances to cut slag from the vents. We find the opposite; we do not have to use a poker more than three or four times a year, but for our linings, which are 94% silica and last about 2½ years, the underpinning is usually in a fairly bad state after about 1–2 years; the small amount of slag made seems to attack the underpinning and leave the vents fairly free.

The advantage of the wet bottom is that it saves so much time in the year and manning can be reduced. With a dry bottom the brickwork is not damaged so much as with a wet bottom. Other factors are the mechanical damage to the crane in making a bottom and the effect on the electrical equipment of the charger crane from the dust that arises from making a dry bottom. We are experimenting on a limited basis at the moment with wet bottoms, but we have no definite data yet. Since the author claims to make very little slag, I should like to know his opinion on this matter.

For a limited time we rolled 6-ton 4% Si ingots. The Americans claim to have some experience in rolling and heating this type of steel, and we were advised to heat 4% Si steel to 2000° F. (about 1100° C.). This steel can be heated and rolled in 6-ton ingots quite successfully at that temperature.

The life of the brickwork in the author's covers of 3–4 years is similar to the life of our covers, using the Simplex Fraser method of suspension with a 40–42% alumina brick. The use of the latter is important, and the bricks must be of very good shape. What type of brick does the author use?

Mr. **W. L. James** (John Lysaght's Scunthorpe Works, Ltd.): The real test of a soaking pit is how quickly and efficiently it can deal with a complete pit of cold ingots. With the layout at our works it is possible to feed the soaking pits with ingots to any given track time, as any heat can be stripped within ¼ hr. of being set; this accounts for the statement by the author that on certain individual casts the heat consumption at the soaking pits has been as low as 250,000 B.Th.U./ton.

I prefer to use a gas with as low a calorific value as possible, because in that way the least damage is done to the steel or the refractories of the pits.

In regard to the much-discussed question of whether to have a dry pit with a coke-breeze bottom or a pit

* More recently, alterations to the burner design have tended to improve pit performance when using oil.

using a fluid slag, I would prefer from experience to use a dry-bottom pit. Much depends, of course, on what is to be done with the pit; *e.g.*, if, in addition to being a soaking pit, it is required to be a wash-heating furnace, the temperatures in the pit are obviously going to be so high as to make slag. On the other hand, if the object of the pit is merely to solidify the steel and to heat it to a uniform temperature high enough for rolling (which in most cases is under 1300° C.), there is very little risk of making any slag, and the dry-bottom pit will be very advantageous indeed. The practice of having ingots standing in pools of slag in the pits is, in my opinion, bad, particularly in the case of rimming steels, because there is always the risk of exposing subcutaneous blow-holes, with the resultant 'shelly' product in the mill.

The scale loss on these pits can be kept remarkably low, and we aim to produce such a scale that, on lifting the ingot from the soaking pit and exposing it to the outside air in transference to the mill, the scale is already cracking and is almost entirely removed as soon as it comes into contact with the cogging rolls.

Mr. **C. H. Williams** (Stein and Atkinson Ltd.): On the question of pit bottoms, it was decided to install a very ample handling scheme for coke breeze at Lysaght's, and this system has worked excellently. There has been no trouble with these bottoms, except during the earliest phases of starting to work. I think, however, that the Company are being over-careful and that rather more breeze is being used than is necessary.

When we later built the blast-furnace-gas fired pits at Consett, the question of pit bottoms was gone into at length, and advantage was taken not only of the experience at Lysaght's, but also of that at Consett on some pits built by us some years before. It was decided not to install any breeze-dumping holes or tunnels, but to dig out the breeze bottoms as required. It is remarkable that after 18 months of operation no digging-out of the bottoms has been required. The charger crane has only to level the fresh breeze, which works out at about 4500 lb. per pit per week, and is equivalent to 3½ lb. per ton of ingot heated. The use of blast-furnace gas only is a contributory factor.

Dr. **D. F. Marshall** (Park Gate Iron and Steel Co., Ltd.) The decision about whether to run with a wet or a dry bottom depends firstly on the finishing temperature of the ingot heated in the pit, and secondly on the time of soaking allowed for that ingot. Has the author found any relationship between the steel quality of the billets produced from the ingot and the finishing temperature in the pit?

AUTHOR'S REPLY

Mr. **A. H. Norris** said in reply: Mr. Thomson asked what we considered to be the best loading for our type of pit. Although not anticipating this question, last week I had 20 cold ingots charged into No. 1 pit, compared with the usual 18 for seven charges. The charge-to-draw figures averaged 1,724,000 B.Th.U., varying from 1,600,000 to 1,900,000 B.Th.U., depending on the quality of steel put in; the charge-to-ready figures averaged 1,570,000 B.Th.U. The charge-to-draw rate was 5·75 tons/hr. and the charge-to-ready rate was 7·19 tons/hr. We cannot charge more than 20 ingots, owing to space and manipulative difficulties; moreover, the gas would not circulate freely.

The influence of track times is important. Our figures for 1953 are similar to the period dealt with in the paper, but the figures for 1954 are not quite so good, as ingots have been standing for a longer period. It is at once possible to see the influence of the additional track time on the pit figures.

Mr. Thomson asked for the gross figures covering not only the times the ingots are in the pits, but also when the pits are empty and when charged during the Sunday preparatory shift. The figure so far this year averages 12½–13 therms/ton; in the two previous years it was about 12 therms/ton. I cannot observe any deterioration in pit performance caused by wear and tear after four years' working.

I was responsible for operating dolomite dry bottoms in our old mills, where the bottoms were dug out every ten weeks, and I much prefer using a breeze bottom. We clean out every ten working days and do not produce any slag on the ingot bottoms—an occurrence that was not infrequent when using dolomite. I do not know of any bleeding taking place; neither do I think there is any infiltration, which would cause less efficiency in soaking.

We do not preheat the steel; this has been unnecessary because we can absorb our ingot output in 16 shifts. When an ingot surplus is accumulated an extra shift can be added as required.

Mr. Ernest questioned the level of the temperature control and the possible sacrifice made compared with the gain in refractory life. The temperatures mentioned in the paper are the ones used now, and we have a record of the cogging-mill loads. Provided that ingots are soaked a difference of 20° C. is not very important. Only on fast rolling orders, where the pit lids are constantly being opened, are the pit temperatures raised deliberately. From a rolling standpoint I see no advantage in raising temperatures to 1300° C.—we have tried it—and Mr. James has already hinted at other evils that might befall if the temperature is raised too much.

Unfortunately I cannot add to the figures given in the paper regarding oxidation losses.

Mr. Slade's remarks about slag were interesting. We make very little slag, and the small amount made is never allowed to build up. With silicon steels in particular (which, if kept in the pits a long time for any reason, inevitably make slag) it is safer to clean out regularly.

Mr. Slade suggests that there might be mechanical damage to cranes by using a dry bottom, and also that the breeze and dust might damage electrical equipment. Certain damage has been done to our cranes, partly through operational and partly through design causes. As the drivers became more expert and when certain modifications were made to the cranes, there was a big all-round improvement. Dust has caused no damage to the electrical installation.

I agree with Mr. James in disliking wet slagging; having experienced this method for many years I have no desire to return to it. Apart from the messy operation and damage to brickwork, at some time or other the ingots are bound to stand in slag, which is very detrimental.

An interesting point was made about the rolling of 6-ton 4% Si ingots at 1100° C. We have drawn ingots of this quality as low as 1180° C., although for general purposes 1220–1230° C. is satisfactory. We do no damage at that temperature, but if the temperature were as low as 1100° C., there would be a danger of breaking the rolls in the Morgan mill, which rolls down to ¼-in. thick bars.

We use a Scotch firebrick to line our covers, the last lid being rebricked three weeks ago. As we have been operating four years, the life of lid bricks is 3–4 years.

Mr. Williams takes the view that we slag our pits too frequently. He is probably right, but we do so deliberately. Anyone who has rolled large quantities of silicon steels knows that risks cannot be taken with this material

in the soaking pits. The difference in cost in our system of slagging a pit every ten days instead of every twelve is not great and is offset by the avoidance of trouble which might otherwise occur.

In reply to Dr. Marshall, if the steel is at too low a temperature on drawing there is a gain in fuel consumption, but operational and steel troubles occur later; if on the other hand, to minimize cracking and operational troubles, the temperature is raised too high, soaking-pit troubles occur. Each plant discovers by experience the best heating temperatures for its products, but I must return to my earlier assertion that the most important factor is adequate soaking rather than temperature.

Discussion on the Paper—
SOME FACTORS AFFECTING THE WEAR OF GRAPHITE ELECTRODES IN THE ELECTRIC-ARC FURNACE*

By the Electric Process Sub-Committee

Mr. **F. T. Bagnall** (Samuel Fox and Co., Ltd.) and Mr. **W. C. Heselwood** (United Steel Companies, Ltd.) presented the paper.

Dr. **A. H. Leckie** (Iron and Steel Board): The Sub-Committee are to be congratulated on making a special study of an item of steelmaking technique which has been rather neglected up to now, but which is going to be much more important in the future. There is a growing interest in the use of electric furnaces for making tonnage steels; it has largely stemmed from the report prepared by the Battelle Institute in the U.S.A., but we in the U.K. have been equally interested in the possibilities for a long time. As will be seen from the previous report of the Sub-Committee,† the concept of making ordinary steels in the arc furnace is by no means new.

The cost of electrodes may be quite a small item in the total cost of a heat of alloy steel, but it is significant for the tonnage steels; in any case, even when making expensive steels there is no excuse for neglecting the opportunity to save several shillings per ton.

Most readers of the paper will comment that the Sub-Committee list at the beginning of the five factors which concern wear and then spend the rest of the paper discussing only one of them. The members of the Sub-Committee, as practical steelmakers, are well aware of the importance of the other four points, but the quality of the electrodes is the one item over which the practical steelmaker has least control. I hope that in their next report the Sub-Committee will discuss the other factors a little more.

For instance, does the decrease in the time of the heat to be expected after an increase in transformer capacity result in a decrease of electrode consumption per ton? That involves an important cost question.

One of the biggest factors governing electrode wear is the surface area of electrode exposed at high temperature. Can the Sub-Committee specify the minimum diameter of electrode applicable to any given size of furnace, bearing in mind its 1949 report, which suggested that most electrodes in this country were run at a current density considerably less than that specified by the makers? If a smaller-diameter electrode is used, the risk of breakage is increased. At one time B.I.S.R.A. even considered the use of water-cooled electrodes, but were discouraged by the calculated heat losses in the cooling water. Could a water-cooled metal core be used for a graphite electrode, which would strengthen the stick, to permit smaller diameter? There is evidence that electrode consumption is strongly correlated with diameter.

In connection with the influence of resistivity on wear, it is not surprising that an acceptance test is recommended. Most steelmaking raw materials are tested before use; refractories are generally subject to inspection for quality, and there is no reason why a consumable material such as graphite should not be treated in the same way.

The histograms of resistivity are based on a small number of electrodes, only that for the Stewarts and Lloyds electrodes being based on a sufficient number to show that the true statistical distribution is skew; that is the distribution to be expected in a scarce commodity, because more samples will deviate from the mean on the wrong than on the right side. Incidentally, the Stewarts and Lloyds electrodes are the only examples which show an appreciable number exceeding the acceptable resistivity figure. Is that due to the greater difficulties in manufacture of the large-diameter electrodes? If so, it suggests that the graphitizing-furnace capacity available to the makers was not then up to the demands likely to be made for large electrodes.

The Sub-Committee may be a little unfair to the suppliers of electrodes in quoting these examples, which were mostly obtained from tests done during a period when the manufacturers were hard put to it to meet the demands of the industry. It would be interesting to have similar histograms prepared from samples of electrodes delivered to-day; a greater percentage should be within the tolerance limits.

The explanation of why electrodes wear more rapidly at the joint is very ingenious. The Sub-Committee suggest that the conditions might be improved by the use of tapered nipples. Are trials being done with these nipples in the U.K.? The value of tapered nipples is an important point to establish. Parallel-sided nipples are now rare in the U.S.A.

The economies which might be attained by improving graphite consumption to a substantial degree may amount to several shillings per ton. Experience in Norway and Sweden shows that even bigger savings can be obtained by using paste electrodes of the Söderberg type. Trials of these electrodes should be carried out to confirm whether or not worthwhile savings can be made in the U.K.

Mr. **D. H. Houseman** (K and L Steelfounders and Engineers, Ltd.): Since the original publication by Brandt and Glaisher,‡ my Company have been interested in the relationship between electrode wear and resistivity,

* *J. Iron Steel Inst.*, vol. 176, 1954, February, pp. 159–165.

† *Ibid.*, vol. 162, 1949, May, pp. 57–78.

‡ D. J. O. Brandt and W. H. Glaisher, *Metal Treatment and Drop Forging*, 1953, vol. 20, pp. 515–516, 524.

measuring the latter quantity by the technique they describe. Figure *A* shows the results of resistivity measurements on a batch of 100 10-in. dia. electrodes, the abscissæ being the means of three resistivity determinations equally spaced along the electrode. This batch has been divided into three groups, having mean resistivities below 900, between 900 and 1000, and above 1000 microhm-cm., respectively. The three groups are being successively used for electrode-consumption trials in two 5-ton basic electric-arc furnaces; results so far indicate that electrode consumption is directly related to resistivity, and it is hoped shortly to report these trials more fully.

I have also examined statistically the relationship between the average bulk density of an electrode and its mean resistivity. In a sample of 100 electrodes the correlation coefficient between these two quantities was found to be −0·199; this is significant (for 100 degrees of freedom) at the 3·4% level of probability and may be taken as a fair indication of a linear relationship between the two quantities. Comparison of Fig. *A* with Fig. 12 of the paper shows the resistivity distributions to be fairly similar, except that the former has a longer ' tail ' towards the higher resistivity values.

Two factors arise in using these higher-resistivity electrodes. The first, that of increased wear in the arc, is serious enough from a direct-cost standpoint, and the second, that of electrode breakage in the furnace, results both in wasted electrode ends and in loss of melting time, since, as Brandt and Glaisher have pointed out, breakages due to ' necking ' of the high-resistivity portions of electrodes usually occur in the early part of the melting cycle, as a result of mechanical stresses set up when the electrodes bore into the scrap. Melting conditions are here at their severest, and removal of the broken electrode end is troublesome at this stage. Doubtless the ' heating ' effect due to the higher resistivity of ' bad ' graphite electrodes near joins is further enhanced by the steady fall in thermal conductivity that occurs with increasing temperature.* Thus, for reasons both of cost and of convenience, the use of high-resistivity electrodes in the electric-arc furnace is undesirable, and we are co-operating with our electrode suppliers in an endeavour to minimize this use.

Mr. **T. H. Mowbray** (British Acheson Electrodes, Ltd.): Some of the troubles of three or four years ago have now largely disappeared. At that time there was great pressure on electrode suppliers, and when it appeared that some trouble had arisen we tightened up our check on electrode resistance, but there has been no change made in our method of manufacturing graphite electrodes.

The possibility of introducing an acceptance test for electrodes has been suggested, but I think a test such as this would be difficult to operate under conditions such as existed when this question of electrode resistance first came up, when, in an emergency, electrode supplies were being obtained from abroad. Some of the imported electrodes which had a high resistance were returned to us in Sheffield, but there is no practical way in which such electrodes which have been machined with nipple jointing for furnace operation can be regraphitized to lower their electrical resistance.

Our check of electrical resistance on a graphitized electrode is made before it is machined for nipple jointing, and in the event of any electrodes of a particular graphitizing heat appearing high in resistance at that stage the material can be regraphitized; such regraphitizing cannot, however, be carried out after the stock has been machined.

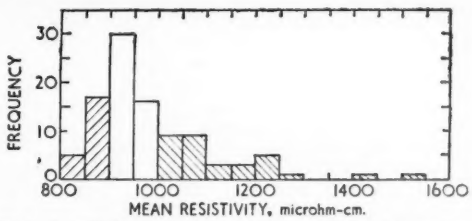


Fig. A—Histogram showing variation in mean resistivity of 100 10-in. dia. electrodes

We have recently changed our method of checking electrode resistance, which should be to the user's advantage, but it is not yet practicable to check every piece for resistance (particularly in the smaller furnace sizes, where for, say, the 3-in. size, there are 150 or more to the ton) without unreasonably adding to the cost of the electrodes, but we believe that our system of examining representative samples from each batch is a very good check.

In regard to the supply of electrodes with tapered nipples, two tests are now being run to determine if these offer any advantage to furnace operators, and a third test will be started shortly. Without wishing to prejudice anyone interested in carrying out these tests, I should say that there are large electrode users, both in the U.S.A. and on the Continent, who, after testing electrodes fitted with the tapered nipple joint, have reverted to the older straight-sided nipple in general use in the U.K.

Mr. **Houseman:** My experimental results for high-resistivity electrodes indicate that resistivity is substantially lower in the middle than at the ends of most electrodes; this leads to serious practical difficulties. I feel that this unevenness can be related to manufacturing techniques. Would Mr. Mowbray outline these techniques?

Mr. **Mowbray:** In converting carbon electrodes to graphite in the electric furnace, the heating current is passed through the cross-section of the electrode and not through the electrode from end to end; occasionally, therefore, when an electrode, after graphitizing, shows high resistance overall, the tendency is for such high resistance to be confined to the electrode ends, which would be near the side wall of the graphitizing furnace.

Mr. **Heselwood:** Mr. Mowbray said that his Company normally subjects electrodes to a resistance test before passing them for machining. What is the top limit of resistance above which an electrode would fail this test ?

Mr. **Mowbray:** For the diameter size range 16 in., 14 in., and 12 in. of graphite electrodes it is 1250 microhm–cm., and for the range 8 in., 9 in., and 10 in. it is 1150 microhm–cm.

Mr. **G. Wood** (English Steel Corporation, Ltd.): The paper overemphasizes the resistivity and does not lay enough emphasis on the surface area. The latter has more to do with the loss of electrode than the resistivity alone, although the two taken together certainly account for a great deal. In addition to the Söderberg electrode, there is the amorphous carbon electrode, which is available in the U.K. We are using this electrode on a number of furnaces and get a much lower cost than with graphite. The steel produced is equivalent to that produced with graphite electrodes. The only reason these are not used on the larger furnaces is that the electrode cannot be made large enough.

Mr. **Bagnall:** The easiest and most convenient electrode to use is the graphite; I prefer to economize to the limit on the graphite rather than have to use the amorphous type. With the Söderberg electrode, the question of size

* " Electric Furnace Electrodes," p. 16 : 1949, New York, National Carbon Co., Inc.

again arises. On my company's new 60-ton furnace it is proposed to use 20-in. graphite electrodes. Three 36-in. holes would be needed in the arc-furnace roof if amorphous or Söderberg electrodes were used.

Mr. **F. Crankshaw** (K and L Steelfounders and Engineers, Ltd.): Mr. Bagnall has raised the point that the use of amorphous carbon electrodes on a 60-ton furnace would present difficulties in roof construction. They would also create a problem in a small furnace with a very high transformer rating (*e.g.*, 3500 kVA.) into a furnace with an 8-ft. or 9-ft. dia. shell, as the increase in the electrode pitch-circle diameter, necessitated by amorphous carbon electrodes, would cause even more serious erosion of the side wall of the furnace.

Mr. **J. C. Howard** (Electric Furnace Co., Ltd.): The graphite electrode is more convenient than the Söderberg, but the latter is considerably cheaper per ton of steel produced than the graphite or the amorphous carbon electrode. Foreign steelmakers use Söderberg electrodes and can compete favourably with our more expensive steels made with graphite electrodes. Development work should be carried out on the use of the Söderberg electrode in the U.K.

The figure of 25*s.* per ton mentioned in the paper for the cost of electrodes is compared with an O.H. fuel cost of 30*s.* per ton. Anyone considering the use of an arc furnace as an alternative to the O.H. furnace might be frightened off by this rather high cost. The figure of 25*s.* per ton is for very high-quality steels, double-slagged steels, probably similar to those normally made in the crucible furnace. For O.H. quality types of steel, a figure of 12*s.* per ton or even lower is more accurate.

The surface area of the electrode must have a very big influence on electrode consumption. Undoubtedly the greater the surface area is, the greater will be the electrode consumption. This leads to the use of a smaller-diameter electrode, and obviously the result will be an improvement if the diameter is not too small. But the length of the electrode also has some influence. It is impossible to alter the length of the electrode within the furnace, because it is dependent on the furnace design itself, and the furnace design has to be a compromise from an electrode-consumption standpoint. The shorter the length of the electrode is inside the furnace, the lower the electrode consumption will be, but with the bulky material which has to be charged into furnaces it is necessary to make the height of the furnace rather greater than the optimum for electrode consumption, to the probable detriment of the latter.

From all that has been said, it is obvious that the efficiency of graphitization is very important in keeping down electrode consumption. It further seems very evident that it is even more important that this graphitization should be complete at the ends of the electrodes.

Mr. Mowbray pointed out that with the normal graphitizing equipment it is inherently more difficult to graphitize the ends. It is understood that for graphitizing, the raw electrodes are placed in the furnace alongside each other so that the current flows sideways across the diameter of the electrodes. Obviously there will be higher radiation loss at the side of this column of electrodes and there will be a tendency for a lower temperature there than at the middle of the column.

Graphitizing is dependent on temperature. As graphitizing proceeds, the resistance decreases. If, then, there is more complete graphitization in the middle of the column than at the edges, there is a progressively increasing concentration of current there, and, in spite of the lowering resistance in the middle, there will be an increasing tendency for still greater difference in temperature between the middle and the outside of the column.

It is suggested that the distribution of the current through this column of electrodes could be controlled by a magnetic field above and below the furnace and could force a greater concentration of current at the edges rather than in the middle so as to give more complete graphitization at the ends of the electrodes.

The **President** (The Hon. R. G. Lyttelton): This paper is of fundamental importance to the electric-furnace side of this industry, and the subject will increase in importance in the future. How long, for instance, will the Bessemer and O.H. processes be in use? That obviously depends on the supply of coal. The latest figure for the life of coal reserves in the U.K. is 200 years, though with the discovery of new coal resources this is not accurately determinable. If 200 years is the maximum period of our coal supplies, the period for coking coal will be considerably less.

It seems that the electric furnace using electricity produced by atomic power may, in the not too distant future, replace the existing processes, and this paper provokes a forward reflection of that kind.

AUTHORS' REPLIES

Mr. **Bagnall:** We agree that any increase in length of electrode below the roof will show an increase in consumption owing to the tapering caused by furnace atmosphere. We also know that present American furnace design favours an increase in roof height to accommodate bigger charges of light scrap. This deeper charge also makes it possible to use higher voltages for longer periods with the nose of the electrode buried in the charge.

The importance of complete graphitization of the electrode has been fully stressed and is accepted.

Electrode consumption can be divided into three distinct sections. Firstly, there is the graphite actually consumed in the process.

Secondly, there are the losses due to mechanical breakages. Generally an electrode length breaks at the nipple. If the nipple is above the roof it can be replaced and the loss is merely weight of nipple. If the break is below the roof the loss is serious and means weight of nipple plus one or two lengths of electrode.

Thirdly, there is the weight which must be lost when the joints actually reach the bath surface or more particularly when they are in contact with the cold scrap during the melting down of the following charge. With the parallel nipple the collar becomes so thin that it is not strong enough to hold the nipple, which is lost together with the collar and any short end below the nipple. The tapered nipple shows big advantages in this respect.

Mr. **Heselwood:** The discussion has revealed that the electrical resistivity test described in the paper is being adopted by further users of electrodes, and any further data that would help to assess the practical value of the test will be of real interest to the Committee.

DISCUSSION ON STRUCTURE OF CAST IRONS

This discussion was based on the following papers, which were published in the *Journal* for April, 1954:

"Eutectic Solidification in Grey, White, and Mottled Hypo-Eutectic Cast Irons," *by A. Hultgren, Y. Lindblom, and E. Rudberg* (pp. 365–374).

"Structural Changes During Annealing of White Cast Irons of High S : Mn Ratios," *by A. Hultgren and G. Östberg* (pp. 351–365).

"The Growth of Nodular Graphite," *by M. Hillert and Y. Lindblom* (pp. 388–390).

"The Solidification of Nodular Iron," *by H. Morrogh* (pp. 378–382).

"Undercooled Graphite in Cast Irons and Related Alloys," *by H. Morrogh and W. J. Williams* (pp. 375–378).

"The Solidification of Iron–Phosphorus–Carbon Alloys," *by H. Morrogh and P. H. Tütsch* (pp. 382–384).

"Decomposition of Cementite During Solidification of Cast Iron," *by A. Berman and V. Kondic* (pp. 385–387).

Professor **E. Rudberg** (Swedish Institute of Metal Research) in presenting the first paper drew attention to errors on p. 368 and on the plate facing p. 370, where 'Iron *A*' should read 'Iron *E*.' Professor **A. Hultgren** (formerly at the Royal Institute of Technology, Stockholm) presented the second paper, and Mr. **Y. Lindblom** (Domnarfvets Jernverk) the third. The fourth, fifth, and sixth papers were presented by Mr. **H. Morrogh** (British Cast Iron Research Association), and the seventh by Dr. **A. Berman** (Birmingham University).

Dr. **N. P. Allen** (National Physical Laboratory): It seems that the brilliant work which has been done by the British Cast Iron Research Association on this subject has encouraged interest throughout the world. We extend a particular welcome to the Swedish authors and admire the high quality of their work, which is such as we always expect from metallurgists of their nationality.

In reading these papers I have been reminded of Dr. Hadfield's book on "Cast Iron in the Light of Recent Research," which appeared so many years ago. It had many iron–carbon diagrams purporting to explain the behaviour of cast iron, but it was very clear that at that time the experimental technique available to the metallographer was not sufficient to settle the problems that arose. Since then technique has improved and accurate pyrometric work at 1130° C. is reasonably easy, and it is very pleasant to see that work of the necessary accuracy is being carried out with material which is controlled closely enough in composition to decide the points at issue.

The paper by Berman and Kondic describes an attack on the isothermal study of the reactions during the solidification of cast iron. This is a correct approach, but the experimental methods are perhaps a little too simple. There is a possible danger in taking the metal down to a low temperature and then heating it again to the temperature at which the reaction is to be studied, because it is not quite certain that the changes which take place are the same as those which would have occurred had the metal never been down to the lower temperature.

In this kind of work it is necessary to work on small amounts of material and to be careful about the amount of refractory surrounding the sample, so that the rate of heating and cooling in the neighbourhood of the temperature chosen for the experiment is rapid when it is required to be rapid and slow when it is required to be slow. Heavily lagged furnaces are not so suitable as more modern furnaces in which one heats by radiation or high-frequency induction, and can have a small amount of experimental material surrounded by relatively little refractory.

Twenty or thirty years ago it was common to think of the γ to α change in steel as taking place in stages, the austenite changing first to martensite, and the martensite through a troostitic stage to pearlite. That conception of the transitions disappeared entirely when the isothermal technique was introduced and it was found that actually the transformation was either directly from austenite to pearlite or from austenite to martensite; it may well be that in the case of cast iron, where we are thinking there is possibly a transition from liquid to cementite eutectic and then from cementite eutectic to austenite plus graphite, it will ultimately be found that the transformation is either from liquid to cementite eutectic or from liquid to austenite plus graphite, and that the supposed succession of transformations is a consequence of imperfect observations.

The spherical form of the graphitized areas in cast iron suggests that the formation of a graphite nucleus is a comparatively rare event, and that any metal that does not come within the sphere of influence of a nucleus solidifies with the formation of cementite. The probability of forming a graphite nucleus depends on the carbon content of the matrix and the critical size of the nucleus. The critical size of the nucleus is greater when the resistance to its formation is increased, and since the formation of a nucleus in the solid is opposed by elastic resistances that are not present in the liquid, it is to be expected that the formation of a graphite nucleus in the liquid would be more probable than its formation in the solid.

If the view is taken that on solidification cementite is always formed first, and that this cementite decomposes to form graphite, a reason must be found for the sudden increase of graphite nucleation rate that takes place immediately solidification is complete. In the absence of such a reason, the process must be regarded as improbable.

If the presence of fine ledeburite in the microspecimen is regarded as evidence that liquid was present when the specimen was quenched, Professor Rudberg has established that fine undercooled graphite can form directly from the liquid; but the Birmingham workers have shown equally that fine undercooled graphite can form in the liquid as well.

It is a question, therefore, of deciding not whether one view is definitely right and the other definitely wrong, but of deciding which process usually takes place during the solidification of ordinary iron castings. If a sequence of changes from liquid to cementite eutectic and then to a graphitic structure is to be accepted, it must be shown that under these conditions a given

area in a specimen during continuous cooling shows first a cementite eutectic structure, and later a graphitic structure.

Another interesting point in this group of papers is the question why the graphite sometimes has a spherulitic form and sometimes has a flake form. The explanation offered by the Swedish authors, that the transition from one form to the other is connected with the relative rates of growth at the edge and on the face of the graphite flake, is acceptable. The sequence of structures from spherulitic to flake graphite observed when the temperature is raised then indicates that the spherulitic graphite is formed when the rate of growth of graphite is, by some action, decreased.

This bears on the very interesting suggestion that screw dislocations are the cause of the formation of the spherulitic form of graphite, for screw dislocations provide a reason why the rate of growth of graphite should increase, whereas the experimental observations seem to require that the spherulitic graphite is associated with slow rates of growth.

The best solution of the difficulty that comes to my mind is that when flake graphite is formed there is a mechanism of growth of the graphite flakes which is independent of the screw dislocations and is rapid. Then something can happen which can arrest the action and enable a slower, different mechanism to operate, that mechanism being dependent on the screw dislocations in some way. The suggestion seems to me to reconcile some of the observations but, of course, the obvious objection to all these speculations is that we have not measured the actual rates of growth of the graphite in either direction. It would be very useful if someone could find a way of doing that.

Professor **A. Hultgren:** At this juncture I should first like to put a question to Mr. Morrogh on a matter of nomenclature. When hypo-eutectic irons solidify austenite is first precipitated and then a second phase appears, which may be cementite or graphite. My view is that at that moment the eutectic reaction is initiated, and this I think is not in accordance with the language generally used by Mr. Morrogh. He speaks of graphite or cementite forming in a hypo-eutectic cast iron before the eutectic reaction. It seems to me that, regardless of the form or distribution of the second solid phase, there must be a eutectic reaction as soon as two solid phases are present; the liquid, where that second phase appears, must be hypereutectic in composition, since there must be some supersaturation before a solid phase forms.

The term ' degenerate ' has been suggested by Hanemann for cases where the second solid phase in a eutectic reaction does not associate itself with the first in a sort of repeat pattern but develops more or less independently, and I gather that the independent phase grows simultaneously with the growth of the first. I think it would be desirable if we spoke the same language in referring to reactions where two solid phases are produced from a liquid.

There is one thing on which I would like to be better informed. I have been looking at mottled iron structures for some time and they appear to be characterized by a matrix of ledeburite in which spheroids of a graphite–austenite aggregate are distributed. If there is another type of mottled structure I should like to know about it. I agree that after graphite–austenite has formed as the eutectic, and ledeburite has superseded it, there may be a continued formation of graphite by decomposition of cementite at the border region between the two. This malleablizing reaction may occur if the composition of the material and the cooling rate are suitable. I still believe, until I find convincing evidence to the contrary, that the spheroidal shape of austenite–graphite units in these cases has something to do with the fact that they form from the liquid.

I well know, and Mr. Östberg and I have demonstrated this in our paper, that graphite aggregates formed during annealing of white iron may have a rounded appearance, but such aggregates are distinguished from those of undercooled graphite by their high carbon content and, consequently, by intervening regions of matrix free from graphite. Evidence on that point would be most desirable. For instance, in Berman and Kondic's paper it might be possible to produce stages of graphitization to show, at proper magnification, the shape of the newly formed units of graphite and austenite and to what extent perhaps remnants of cementite are present in it. As a metallographer I am not yet convinced that this proposed transition from the ledeburite to the graphite type of structure has been sufficiently elucidated, showing the sequence of the reaction.

On the so-called ' degenerate ' structures, I imagine Mr. Morrogh and Mr. Tütsch would agree to regard the first appearance of fairly heavy cementite bands or needles as the evidence of degenerate binary eutectic, with austenite being deposited simultaneously. In this system, where phosphorus has to be concentrated in the liquid, both on the precipitation of austenite and of cementite, one should not be surprised to get that type of degenerate structure; I should say that as soon as you find the cementite the binary eutectic reaction has set in. Finally, the ternary eutectic is obtained.

In the interesting new work of Morrogh and Williams, there is, of course, an attempt to provide detailed evidence in the structure for the sequence of reactions, but I think it requires some amplification. For instance I and my Swedish colleagues would like to see individual cooling curves for each experiment, to prove that you have succeeded in reproducing identical conditions for a whole series. I shall be quite happy to agree with you if you provide the conclusive evidence, but so far I am not convinced that the conclusion is correct.

Dr. **R. V. Riley** (Staveley Iron and Chemical Co., Ltd.): The fundamental conception of the metallurgy of cast iron has for many years been undergoing a change. In the early days of Professor Turner the simple iron–carbon diagram appeared capable of representing cast iron alloy sufficiently accurately. Now, thanks to recent developments in the malleable field and with nodular graphite irons, this simple concept does not appear to be adequate. Graphite formation has, of course, received most attention and with it the equally important subject of carbide formation and breakdown. The work at the British Cast Iron Research Association has, I would think, demonstrated the existence of a silico-carbide in addition to cementite, thus confirming the original ideas of W. H. Hadfield and, much later, many other workers, including myself.

The vexed problem of where the graphite in the iron comes from—whether from the liquid or the solid—has in the papers been apparently solved by a compromise. It comes from both. The British workers indicate that graphite in hypo-eutectic iron can come directly from both the silico-carbide and from cementite, and this is quite an important conclusion, although not completely acceptable to our Swedish friends.

The nature of the phosphide phase in iron has been made almost childlike in its simplicity, thanks to the work of Morrogh and Tütsch. The form of the iron–carbon diagram is still a major unknown quantity although I think we can hope for some further excellent work from Sweden and the B.C.I.R.A. on the use of this diagram in elucidating the metallurgy of cast iron.

I would ask Mr. Morrogh to say more about the composition of the silico-carbide to which he has referred. I am interested to see that the analysis quoted on p. 377 indicates that the two carbides—the cementite and the silico-carbide—can have very variable compositions. I would like to know whether the authors consider that the two carbides are mutually soluble or whether there are other carbides forming a series of carbides of fixed composition.

I would also ask the authors whether they distinguish between the carbide which occurs sometimes, much to the consternation of foundrymen, in the very centre of a casting. That is known as inverse chill or internal chill. Can a distinction be made between that and the normal forms of chill produced on the outside of a casting?

I am also greatly interested in Professor Hultgren's reference to the effect of hydrogen and I would venture to ask him whether he had confirmed that the effect of hydrogen is a direct action, or does it have some indirect action in its effect on graphitization? Incidentally, I think this paper could be improved by reference to the hydrogen content of the solid iron as well as the hydrogen content of the gaseous phase surrounding it.

Mr. **T. H. Turner** (British Railways Metallurgy Division): The study of cast iron started with chemistry ascertaining what elements were put into it, and now we are at the stage of metallography seeking what structures we have produced. As one examines these metallographic masterpieces one may feel that cast iron is getting so complicated as to be beyond the ordinary user's understanding. Despite the complication of the subject, however, there is no doubt that great progress is being made. Those who do not follow the proceedings of the Institution of Mechanical Engineers may like to know that on 30th April, Mr. S. B. Bailey presented a paper which was, for the engineering user, a helpful summary of the present position and future prospects of nodular cast iron.

It must have been 30 years ago when I first met Professor Hultgren; about that time Dr. A. B. Everest, who was then working in our Birmingham University Metallurgy Research Laboratory, surprised the Director of the Cast Iron Research Association by producing a cast iron of 16 tons. Nowadays specifications for cast iron of 35 tons are discussed as commercially available engineering material; this has been a formidable jump to new materials, which we hardly know whether to call cast iron or cast steel. In this country a new chapter in metallography was opened by Morrogh who helped us to understand what was in cast iron by metallography superior to what we had seen before.

Professor Hultgren and I both had the advantage of studying to some extent under Professor Hanemann; all these Swedish photomicrographs would have charmed Hanemann who would have found them academically pleasing and instructive. Thirty years ago, when I was teaching metallography in Birmingham University, we certainly could not produce photomicrographs such as we have been shown today: they are valuable new developments.

Would the Birmingham workers please say what is the magnification of their Fig. 4 on p. 387? No mention is made of how the photomicrographs were obtained, except that the name of the instrument used is given in one of the Swedish papers. Perhaps Mr. Morrogh would therefore also tell us what type of photomicrographic apparatus he used? I think we really require, at the end of this type of paper, a note saying that $\times$ 100 or $\times$ 200 for a particular worker has included for illumination a prism, plane glass, or whatever the illumination system was; we also need details of the objective, eye piece, and so on. Because one can obtain the same magnification in many different ways, this information is needed to understand and compare photomicrographs produced by different techniques.

I notice that 11 different magnification steps have been used in the Swedish papers, and the magnifications are different from those we tried to standardize for use in publication; is this a deliberate change in policy? Mr. Morrogh uses six steps in going from a magnification of 60 up to 2000, whilst the Swedish workers use 11 steps in going from 100 to 2000. It helps the reader to limit the number of steps and to know how the various magnifications were obtained. I make that comment because we have not previously had such excellent metallography of cast iron. It will be studied by many people who will strive to learn how to polish and etch and photograph these materials and that is why, to help them understand, I suggest there should be added a note regarding the apparatus used, and the magnifications should, if possible, be limited in future.

Mr. **G. Östberg** (Foundry Division of the Swedish Federation of Mechanical Engineering Industries, Stockholm): The work of Mr. Hillert and Mr. Lindblom, who have introduced the use of a radioactive tracer technique for detecting foreign elements in graphite in cast iron, is greatly appreciated. This method of examining the graphite without first removing the matrix by chemical means, as has usually been done in earlier attempts, eliminates much of the risk of interchange of matter in either direction between the graphite and the surrounding material during the preparation.

As the spherulitic growth is said to depend upon an especially high content of foreign elements, it should be important for the authors' hypothesis if a proof could be given that flakes actually do contain less cerium than do the spherulites, for instance, in an iron treated so that both these forms of graphite appear.

The cerium atoms in the graphite spherulites are supposed to be attached to the edge of a growing basal plane of graphite. This arrangement should be compared with the results of an X-ray investigation by Schleede and Wellmann[1] of natural graphite which had absorbed sodium or potassium. The foreign atoms were found to be located between the basal planes of carbon. There were thus two sets of basal planes, one of carbon atoms and one of foreign atoms.

An observation made by Professor L. Meyer at the University of Chicago[2] throws some light on the authors' views of spherulitic growth. Carbon from CH_4 decomposing at high temperature and low pressure was precipitated on a lamp filament of carbon. A section through the precipitate perpendicular to the axis of the filament reveals in polarized light a structure very similar to that of a section of a graphite spherulite (Fig. *A*). The dark spot in the centre is the filament from which the structure of the deposited graphite radiates. Since the graphite formed was spectrographically pure, hydrogen is the only foreign element which could have played any rôle for the manner of growth. This case might perhaps be a parallel to the favourable influence of hydrogen on the formation of spherulitic graphite in some malleable irons, as shown by Hultgren and Östberg.

In a discussion of changes in the direction of fastest growth the work by Möller on salol should be taken into consideration.[3] Separate crystals of salol, formed in the melt, were found to have different crystallographic directions of fastest growth depending upon the temperature of formation. In spherulites of salol, investigated by Jansen,[4] the crystallographic direction

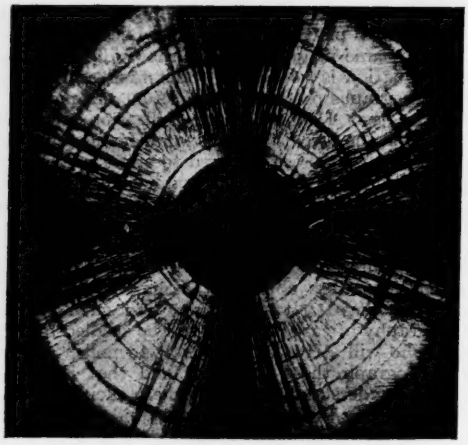


Fig. A—Section of carbon precipitated from methane (L. Meyer) × 200

pointing radially was found to be the *c*-axis at a low supercooling and the *a*-axis at a higher degree of supercooling. Could the authors elaborate the importance of supercooling for their model of changes in growth rate?

Mr. Hillert and Mr. Lindblom refer to the extensive studies of spherulites by Bernauer, who claims that spherulites are formed by the dividing, during growth, of nearly perfect crystals into sub-crystals (German *Sub-Individuen*) whose directions of fastest growth deviate from that of the first-formed crystal. Bernauer attributes this process to the interference of foreign matter with the growth. It should be remembered, however, that a direct application of Bernauer's model on graphite should give aggregates with the *a*-axis directions pointing radially. Such formations are not frequent but can be seen in Fig. 64*b* of the paper by Hultgren and Östberg. Thus it must be emphasized that the influence of foreign matter according to the Bernauer hypothesis is not sufficient to explain the formation of ordinary graphite spherulites, where the *a*-axis directions are tangential.

Mr. Morrogh and Mr. Williams in their paper on 'undercooled' graphite confine their hypothesis on graphitization of ledeburite during cooling in the eutectic range mainly to irons which upon rapid cooling give acicular carbide. That flake graphite can occur as the result of decomposition of *ordinary* ledeburite is shown in Fig. *B*. The flakes seem to have followed during growth the austenite/cementite interface, whilst some austenite (marked by arrows) is seen to have formed between the graphite and the massive carbide. Evidently, the structure of the ledeburite has determined the shape of the flakes and their interrelation in space, as has been predicted in the paper by Hultgren, Lindblom, and Rudberg.

Other cases of carbide imposing its form upon growing graphite in an Fe–Ni–C alloy are seen in Fig. *C*. The main point here, however, is that the spherulites are located in the last solidifying parts of the alloy. This photograph, like those shown by Mr. Morrogh in his paper on nodular iron, disproves the belief sometimes held that graphite spherulites generally form in the centre of the austenite dendrites.

Finally, a comment of perhaps minor importance should be made on the paper by Dr. Berman and Dr. Kondic. These authors compare the time for isothermal graphitization of a white iron below the eutectic range with the length of the eutectic arrest when type *D* graphite is formed. It is known that the rate of malleablization of a ledeburitic structure is greater the finer the ledeburite. In the present case the white iron samples to be annealed were cooled faster and consequently got a finer ledeburite than the iron which passed through the full cooling curve giving type *D* graphite. The isothermal graphitization times found should therefore be corrected to higher values owing to the finer ledeburite.

Dr. **W. S. Owen** (University of Liverpool): Regarding the paper by Hultgren and Östberg I should like to offer some evidence in support of their dissension from the view that the habit of graphite is dictated by the ty, o lattice of the nucleating particle by the suggested mechanism of epitaxis. Recently, at Liverpool, Mr. Wilcock has been carrying out a quantitative study of nucleation in pure Fe–C–Si alloys. The general kinetics of the graphitization reactions in these alloys have been described by Burke and myself.[5] From this earlier study it was clear that nucleation in the malleablization process in these alloys invariably occurs at a cementite/austenite interface and thus nucleation frequencies, if they are to be measured quantitatively, must be expressed

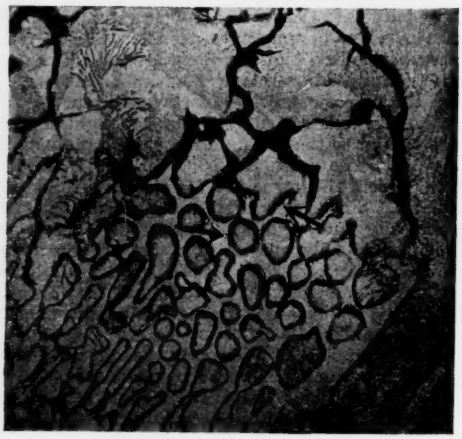


Fig. B—Graphite flakes formed by decomposition of ledeburite × 800

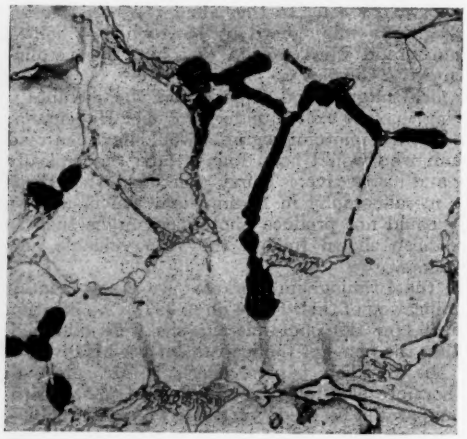


Fig. C—Graphite spherulites and carbide in a Mg-treated Fe–Ni–C alloy with 40% Ni × 750

in terms of the number of nuclei formed per unit time per unit interfacial area. Since this area decreases with annealing time, it is necessary to measure both the number of nuclei and the interfacial area at time intervals during the reaction to obtain the nucleation frequency. Mr. Wilcock has measured the number of nuclei per unit volume (N_v) by the method described in the earlier paper,[5] and the interfacial area per unit volume (S) by a microscopic lineal-analysis method described by Smith and Guttman.[6] The nucleation frequency per unit interfacial area is given by

$$\frac{dN_s}{dt} = \frac{S \cdot \frac{dN_v}{dt} - N_v \frac{dS}{dt}}{S^2}$$

Our results were obtained in an alloy which contained 3·38% C and 1·13% Si, malleablized at 972° C. The graphite was of the aggregate nodule variety. The full curve (Fig. *D*) shows the measured nucleation frequency up to about 70% transformation, since at later times 'impingement' of the nodules invalidates the nuclei count. The curve is of the form which has been deduced from theoretical arguments by Turnbull.[7] It demonstrates that in terms of interfacial area the nucleation is transient and homogeneous. Had the nucleation been induced by the presence of microscopic or submicroscopic particles situated at the interface, as has been suggested by several people, the number of nucleation sites would be limited and, as has been shown by Avrami,[8] one would anticipate the curve to be as shown by the dotted line. This, then, we take as evidence that nucleation sites provided by foreign particles are not features of this kind of graphitization.

From this and similar evidence we take the view that the nucleation problem in white cast irons is essentially one of determining the free energy required to form a graphite nucleus at the austenite/cementite interface, unaided by the presence of foreign particles, and the study of the influence on this energy relation of added elements which can be present, and possibly concentrated, at the interface. The urgent need at the moment is reliable quantitative experimental data relating to nucleation frequencies. There is little doubt that before anything approaching a complete understanding of the phenomena can be obtained, serious attention will have to be paid to measuring the austenite/cementite interfacial energy and the grain-boundary diffusivity of carbon both in pure Fe–C–Si alloys and in more highly alloyed irons. All this does not mean that we wish to disagree with Hultgren and Östberg's approach or their findings, but rather to emphasize, as they have done, that the presence of sulphide particles, etc., is a special and not, as others have stated, the general problem.

We are continuing the work of measuring nucleation frequencies and, by the same lineal-analysis technique, are measuring rates of growth of the graphite, and solution of the cementite, with the object of obtaining a quantitative knowledge of the kinetics of the component processes of the graphitization reaction. We intend to publish these data in the near future.

Next, I would like to refer to the paper by Morrogh and Williams and in particular to the section headed 'Undercooled Graphite in High-Silicon Irons' (p. 377). In connection with their extensive summary of the earlier work of my colleagues and myself I would like to consider two points. The first, a small matter, is that there is no significance in the fact that we were able to detect the Marles carbide in alloys with 2·7% Si by microscopical methods, but much greater quantities of the constituent had to be present (6·0% Si alloys) before we could detect it by our X-ray method. It

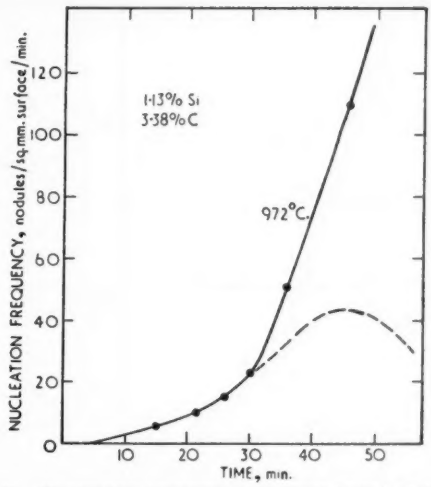


Fig. D—Nucleation frequency per unit interfacial area for alloy annealed at 972° C.

merely means that the X-ray method was a good deal less sensitive than the microscopical method and it may well be that newer X-ray methods will show an appreciable improvement.

Secondly, I agree our earlier work suggests that an Fe–Si–C (or 'silico-carbide') phase does need to be considered in connection with the high-silicon end of our ternary Fe–C–Si diagram. So impressed were we by this fact that at the time we summarized our limited knowledge of the possible silico-carbide phases in a separate paper. All the evidence suggested to us that a stable (or possibly metastable) silico-carbide phase should be brought into the high-silicon part of the diagram probably by the introduction of a second four-phase plane. However, since the available data were far from sufficient or conclusive for this purpose, and at the time we were unable to undertake the extensive programme of work necessary to investigate the matter, we confined our ternary-diagram studies to the liquidus and solidus surfaces of the diagram in the region where, as we showed by quenching experiments, only the four phases—liquid, austenite, ferrite, and cementite—were involved. It is necessary to emphasize that the so-called equilibrium diagram is concerned only with relationships between phases which are stable, or, as in this case, strongly metastable at the temperatures concerned. Consequently the authors' statement that "quenching experiments on irons containing 7·0% of silicon give only silico-carbide" is irrelevant and does not impinge upon the discussion of the structures of the slowly cooled high-silicon alloys, which is given in our reported work on the diagram.[9]

It is my view that the ternary equilibrium diagram is far too useful a concept to be treated lightly and that before dismissing it in the perfunctory manner adopted by Morrogh and Williams their evidence should be scrutinized to see if their microstructure can be explained in terms which are compatible with the diagram as we now have it. If not, their work should be developed with the object of extending the diagram to incorporate their data. As a contribution to the first of these objectives I would like to offer a tentative alternative explanation of their photomicrograph, Fig. 5. I suggest that their 'silico-carbide' is not Marles carbide but is the silico-carbide which in the past we have called '*X*-constituent.'[10] We have shown that austenite

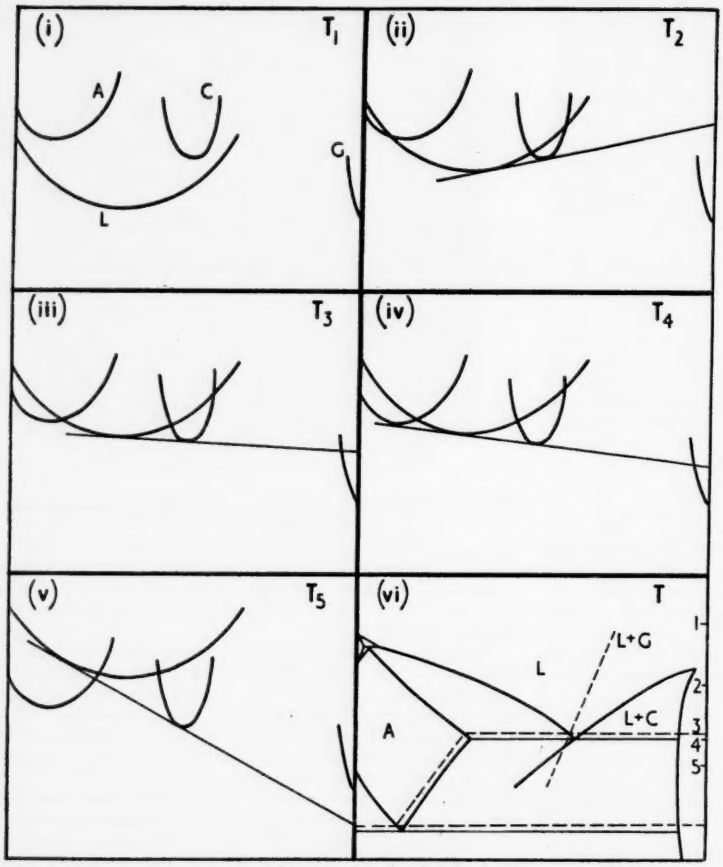


Fig. E—Free-energy/composition and temperature/composition diagrams of the Fe–C system

containing a large concentration of silicon can decompose to form *X*-constituent and ferrite. It is reasonable to postulate that the 6·0% Si alloy shown in Fig. 5 has solidified as the normal undercooled austenite–cementite eutectic. On slow cooling the structure decomposes to give undercooled graphite, but on rapid cooling from the eutectic the graphite separation from the austenite component is suppressed in favour of the more easily nucleated precipitation of *X*-constituent. Dr. Street and I have previously reported[10] observations on high-silicon austenites which demonstrate that the *X*-constituent, although metastable with respect to graphite, is more easily nucleated and thus in low-carbon or rapidly cooled alloys is persistent. If this explanation is accepted the structure is then completely in accord with our equilibrium-diagram studies. There is no question of the silico-carbide forming at the expense of cementite and the basis of Morrogh and Williams's plea for the Fe–C–Si to be considered as a unique exception to the physical laws of metastable equilibrium is destroyed.

Mr. **Y. Lindblom** (Domnarfvets Jernverk, Sweden): In the paper by Hultgren and Östberg the authors observe graphite flakes with curved growth. This has, interestingly enough, parallels among other systems; examples have been shown of curved growth caused by foreign additions as a sort of intermediate step to spherulitic growth. If the growth of a flake is curved enough the result can possibly be a spherulite. The authors show pictures where graphite flakes occur alongside sulphide particles but without any tendency to grow around them. In other specimens where graphite nodules are formed the graphite grows around the sulphide particles. Does it not seem probable to assume that the graphite surrounding the sulphide particles actually from the beginning has the tendency to give spherulites and because of that covers the sulphide particles?

In his paper Mr. Morrogh has shown fine-pattern areas with the same pattern as carbon eutectic, and from this he concludes that these areas are traces of original carbide. It may very likely be so, but there are other possible explanations for this phenomenon. In the ordinary flake eutectic the graphite flakes grow first and the austenite takes up the space between the flakes. In the carbide eutectic it is the other way round: the cementite envelops the austenite and takes up the space between the austenite branches. In the last stages of solidification the temperature has been lowered and the remaining melt is highly enriched with nickel; both these things may give a finer dividing of the austenite branches, the size of which is thus reduced to the same order as the austenite branches in the carbide eutectic, causing a similar pattern.

In the paper by Mr. Morrogh and Mr. Williams the authors had intended to prove that undercooled graphite is formed after the appearance of ledeburite. Figures 2*b* and *f* undoubtedly show the normal solidification of ledeburite. The ledeburitic solidification is yet not finished in ingot 4, as shown in Fig. 2*f*, nor is it shown in ingot 5, Fig. 2*g*. The argument hangs on Fig. 2*h*: we know from Fig. 2*g* that in these specimens there is still liquid iron present when it is quenched. The ledeburite in contact with the graphite eutectic in Fig. 2*h* seems to be fairly fine in some areas. This points to the fact that the graphite eutectic may have been at least partly surrounded with liquid iron when it was quenched, in which case the evidence is not entirely conclusive.

CORRESPONDENCE

Mr. **M. Hillert** (Massachusetts Institute of Technology) wrote: Berman and Kondic present in their paper a very instructive set of free-energy diagrams for the Fe–C system at four different temperatures. Unfortunately the liquid curve *L* has been drawn too low on the right-hand side. According to their Figs. 1*c* and *d* cementite will have a melting point between T_3 and T_4, which does not seem probable; T_3 is the eutectic temperature for liquid ⇌ austenite + graphite and T_4 the eutectic temperature for liquid ⇌ austenite + cementite. Figures *E*(i)–(iv) show that a much more likely melting point for cementite can be obtained by a small adjustment of the liquid free-energy curve. In these

diagrams the intersection which the common tangent to the L and C curves makes with the 100% carbon axis represents the carbon activity of cementite in equilibrium with liquid. It is evident that as the temperature decreases from T_1 to T_4 this carbon activity approaches that of graphite, and that at an even lower temperature T_5 it is actually less than that of graphite (Fig. E (v)). This possibility has also been demonstrated by another method.[11] According to the free-energy curves, Figs. E(i)–(v), the liquid/liquid + graphite and the liquid/liquid + cementite boundaries will therefore intersect as shown in Fig. E (vi).

The Fe–C diagram in Fig. E (vi) provides a good explanation of the reactions involved in solidification of cast iron. Consider a melt of eutectic composition that is cooled slowly. When the temperature falls below T_3 graphite can start to form but not cementite. A very slowly cooled melt therefore solidifies grey. With faster cooling the melt can supercool below T_4 and formation of cementite is thermodynamically possible. At temperatures slightly below T_4 the supersaturation with respect to graphite is, however, greater than that with respect to cementite. The fact that the two phase boundaries intersect reveals that, at further decrease in temperature, saturation with respect to cementite increases more than that with respect to graphite. At T_5 the melt has become more supersaturated with respect to cementite than with graphite. It therefore seems quite natural that rapid cooling favours cementite formation. The picture of the solidification of cast iron, given in the paper of Hultgren, Lindblom, and Rudberg, agrees well with these considerations and there seems to be no thermodynamical possibility for formation of cementite above the eutectic temperature as Morrogh and Williams claim in connection with Figs. 2*c* and *d* in their paper on undercooled graphite. The presence of so-called acicular cementite in these micrographs can be explained as follows. Suppose a melt is quenched from a temperature above that of the eutectic. To avoid coarse eutectic structure (*i.e.*, acicular cementite) the sample must pass very rapidly through a critical-temperature region, slightly below the eutectic temperature. The cooling curve for a point inside the sample will be of the form shown in Fig. F if the surface temperature is reduced to a low value instantaneously and does not rise appreciably thereafter. The cooling rate through the critical region, where coarse eutectic can be formed, will therefore increase with increasing quenching temperature. This would account for the progressive increase in the proportion of acicular cementite shown in the sequence of micrographs Figs. 2*b*–*e*. It therefore seems reasonable to suppose that the acicular cementite has been formed during the quenching and not ' before the eutectic arrest ' as suggested by Morrogh and Williams.

Mr. **B. E. Hopkins** (National Physical Laboratory) wrote: The weight of evidence in the papers on undercooled graphite by Hultgren, Lindblom, and Rudberg and by Morrogh and Williams seems to be in favour of the conclusion drawn by the Swedish authors that undercooled graphite generally forms directly from the melt rather than from carbide as maintained by the B.C.I.R.A. authors. The correlation between the cooling curves and the resulting microstructures obtained by Hultgren and his colleagues is convincing. The experimental evidence given by Morrogh and Williams can be interpreted in an alternative manner which is consistent with the interpretation put forward by Hultgren and his co-workers. A cardinal point in the argument of Morrogh and Williams is that needles of hyper-

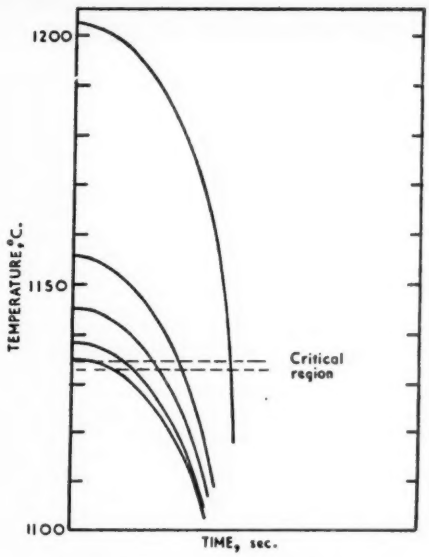


Fig. F—Tentative cooling curves showing different rate of cooling through a critical region

eutectic carbide form before the eutectic arrest; that is, it is assumed that these needles form before the sample is quenched when the quenching temperature is above the eutectic arrest. There is no proof that this is so. The essential point is that what is undoubtedly white iron eutectic becomes coarser as the temperature of quenching from above the eutectic arrest is lowered. This is clearly seen, for example, from Figs. 2*d* and *e* facing p. 376. Since, during a quench, the rate of cooling in the first short time interval at the beginning of the vapour stage is substantially slower than at subsequent stages, the time taken near the eutectic arrest is longer the lower the temperature of quenching from above the eutectic arrest. In other words, the temperature interval in which formation of the white iron eutectic shown in Fig. 2*e* for the sample quenched from 1139° C. took place is higher than the temperature of formation of the finer eutectic in samples quenched from higher temperatures. This explains the increasing coarseness of the eutectic as the temperature of quenching is lowered. I think that what Morrogh and Williams call hypereutectic carbide needles should be regarded as part of the eutectic, and their increasing size with decrease in quenching temperature is thus also explained. The basis on which they maintain that undercooled graphite forms from carbide is thus amenable to an alternative explanation which is in accord with the work of Hultgren, Lindblom, and Rudberg.

The supporting evidence given by Morrogh and Williams at the top of p. 377 is questionable. They say that the undercooled graphite areas often seem to take their form from the carbide particles but their evidence for this statement needs considerable elaboration to be convincing. The average metallographer probably finds it difficult to see much resemblance between ledeburite and undercooled graphite, so that on this count alone the formation of undercooled graphite directly from the melt is a more attractive proposition. As Morrogh and Williams maintain that undercooled graphite forms from carbide, the onus would appear to be on them to reconcile what others would regard as a lack of similarity in appearance of carbide eutectic and undercooled

Table A

RANGE OF β-PARTICLES IN GRAPHITE AND NICKEL

β-Particle Energy, MeV.	Range in Graphite, μ	Range in Nickel, μ
0·1	58	14
0·2	180	45
0·5	763	190
1·0	1350	347
2·0	4490	1123
3·0	7200	1800

graphite by showing stage by stage how the undercooled graphite forms from the carbide eutectic.

Dr. **A. B. Michael** (Allis-Chalmers Manufacturing Co., U.S.A.) wrote: The screw dislocation mechanism proposed by Hillert and Lindblom for the growth of nodular graphite is an interesting approach to an important problem. The authors suggest the entrapment of foreign atoms as a necessary condition for the growth of nodular graphite. However, nodular graphite has been produced in vacuum-melted nickel–carbon–silicon and iron–carbon–silicon alloys of very high purity without the addition of nodularizing elements.[12] The writer has also produced true nodular graphite having the characteristic spatially radial growth pattern in an alloy containing the following analysed percentages: C, 3·0; Si, 1·98; S, 0·002; P, 0·002; and Mn, 0·001; this was vacuum-melted and cast under a pressure of 0·5μ. The interpretation of these results is that the absence rather than the presence of surface-active elements promotes spherulitic graphite formation.

The dark areas on the autoradiographs corresponding to the position of the nodular graphite may also be explained by considering the difference in the range of β-particles in graphite and nickel. The range in graphite is approximately four times that in nickel, as shown by the values in Table *A*, which were determined from the range/energy relation given by Glendenin.[13] At the graphite locations a darker area would be produced on the autoradiograph since more β-particles are striking the emulsion from the radioactive material outside the graphite but not necessarily from radioactive constituents entrapped in the graphite. Holes resulting from the removal of graphite during polishing would produce even more darkening on the autoradiograph in the vicinity of the holes.

The presence of interfering elements made radioactive by activation *in situ* should be considered from the standpoint of their segregation in the matrix of the final cast structure in addition to the overall activity produced by them. For example, microsegregation in the solid solution of aluminium-rich aluminium–copper alloys has been studied by quantitative autoradiography[14] and was found to be quite pronounced because of non-equilibrium solidification. The microsegregation of interfering elements from the starting materials or the microsegregation of the components of the *mischmetall* itself may account for the unexplained dark areas in the autoradiographs.

The writer would like to point out that the cobalt content of the nickel used in these experiments would have to be quite small. The activities produced by cobalt and cerium are compared in Table *B*. The activity produced by the reaction Co^{59} (n, γ) Co^{60} was calculated for the neutron flux, activation time, and pause time used by the authors.

Table B

ACTIVITIES PRODUCED IN CERIUM AND COBALT

	After Activation for 1 Month	After a Pause of 2 Weeks
Ce^{141}	25 mc./g.	19 mc./g.
Co^{60}	37 mc./g.	36·9 + mc./g.

Dr. **A. Berman** (Department of Industrial Metallurgy, Birmingham University) wrote: I should like to make several comments on some points which arise from the paper of Professor Hultgren, Mr. Lindblom, and Professor Rudberg.

The first point is that of definition. It seems to me that the graphite called ' fine undercooled ' in their paper is not exactly the same graphite which Dr. Kondic and myself called graphite type *D*, since (*a*) in our case all the graphite throughout the specimen has the same degree of fineness, and (*b*) the rosette-like units were not observed.

The second point is a theoretical one and concerns iron *C*. In this series of experiments, according to the authors, ledeburite forms at a higher temperature than graphite (Figs. 16*a*, 17*a*, 18*a*). This suggestion is very implausible on theoretical grounds, as it is known that cementite is the metastable phase and should always solidify at a lower temperature than the stable one. The reason for this can be seen clearly in the free-energy/composition diagram, which is Fig. 1 in the paper by Dr. Kondic and myself. It is shown there that cementite can form only if graphite is not nucleated at T_3, and only upon further cooling to T_4 will it begin to solidify. This principle of the formation of a metastable phase at a lower temperature than that of the stable one is a general thermodynamic principle from which it will be very difficult to break.

One point which I would like to raise in connection with the paper of Mr. Morrogh and Mr. Williams concerns the temperature at which cementite begins to solidify. According to the authors the acicular carbide in a hypo-eutectic alloy begins to solidify at a temperature about 10° C. above the eutectic arrest.

This statement does not accord with the accepted modes of solidification of eutectics. The evidence brought forward to support this statement, *i.e.*, the change in slope of the cooling curve at 10° C. above the eutectic arrest, seems to be due to experimental difficulties in obtaining sharp eutectic arrest with small samples at high rates of cooling.

AUTHOR'S REPLY

Dr. **V. Kondic** (in reply): The essential character of our work, as indicated by Dr. Allen, is the study of the structures of cast iron formed under isothermal conditions. Several techniques, other than that described in the paper, are possible, two of which I shall briefly describe. The first consists of melting the sample, cooling it rapidly to produce white iron, and transferring it immediately to an isothermal lead bath. The second has more of a technological character, but nevertheless is a good method of showing that *D* graphite can form by the decomposition of Fe_3C in the solid state. The metal is poured into a water-cooled copper mould by the semi-continuous process, when only a thin skin forms. The rest of the metal is still molten when this skin leaves the mould. Now this skin is almost certainly ledeburitic, but owing to the liberation of the heat of fusion from the central part of the ingot, it is reheated and is found at room temperature to be entirely *D* graphitic. These and similar results have convinced us that *D* graphite can form readily by the decomposition of cementite. Two problems are now receiving our attention: (*a*) What other forms of graphite, normally

believed to form directly from the liquid, can form in the solid state and from what phases do they form, and (*b*) What are the basic factors causing the peculiar nature of the formation of graphite in cast iron ?

[Written replies from Professor **A. Hultgren,** Mr. **W. J. Williams,** Mr. **H. Morrogh,** and Mr. **Y. Lindblom** will be published in the November *Journal.*]

REFERENCES

1. A. SCHLEEDE and M. WELLMANN: *Zeitschrift für physikalische Chemie*, 1932, vol. 18, ser. B, pp. 1–28.
2. L. MEYER: Private communication.
3. H. MÖLLER: *Zentralblatt für Mineralogie, Geologie und Paläontologie*, 1925, vol. 5, pp. 131–143.
4. W. JANSEN: *Zeitschrift für Kristallographie*, 1933, vol. 85, ser. A, pp. 239–270.
5. J. BURKE and W. S. OWEN: *J. Iron Steel Inst.*, 1954, vol. 176, pp. 147–155.
6. C. S. SMITH and L. GUTTMAN: *Trans. Amer. Inst. Min. Met. Eng.*, 1953, vol. 197, pp. 81–87; *J. Met.*, 1952, vol. 4, Jan.
7. D. TURNBULL: *Metals Technology*, 1948, vol. 15, No. 4, Tech. Publ. 2365.
8. M. AVRAMI: *J. Chem. Phys.*, 1939, vol. 7, pp. 1103–1112.
9. J. E. HILLARD and W. S. OWEN: *J. Iron Steel Inst.*, 1952, vol. 172, pp. 268–282.
10. W. S. OWEN and B. G. STREET: *Ibid.*, 1952, vol. 172, pp. 15–18.
11. M. HILLERT: *Acta Met.* (in the press).
12. J. KEVERIAN, H. F. TAYLOR, and J. WULFF: *Amer. Foundryman*, 1953, vol. 23, June, pp. 85–91.
13. L. E. GLENDENIN: *Nucleonics*, 1948, vol. 2, No. 1, p. 16.
14. A. B. MICHAEL and M. B. BEVER: *J. Met.*, 1954, vol. 6, Jan., pp. 47–56.

Joint Discussion on the Papers—

NEW SWEDISH MILL DESIGNS AND LAYOUTS FOR MEDIUM AND SMALL SECTIONS AND WIRE ROD*

By E. Norlindh

THE NEW FAGERSTA WIRE-ROD MILL†

By K.-E. Pihlblad

ROLLER-BEARINGS IN SWEDISH ROLLING MILLS AND THE S.K.F. ROLLING-MILL DESIGN‡

By A. Leufvén

PRACTICAL EXPERIENCE IN THE USE OF REPEATERS IN A LOOPING MILL§

By H. W. Riddervold

Mr. **E. Norlindh** presented his paper.

The second and third papers were presented by Mr. **A. Leufvén,** who showed a slide which compared the old conventional type of housing with the new pre-stressed type.

Mr. **H. W. Riddervold,** in presenting his paper, said: The requirements for the rebuilding of the mill were that: (i) the mill had to remain in the old building; (ii) annual production had to be increased from 28,000 tons to nearly 60,000 tons; (iii) no delay in production could be allowed; (iv) man-power had to be decreased; (v) capital costs had to be minimized.

After showing some slides illustrating the new installations, he said: It was soon realized that the heavy reductions taken in the old hand-operated mill could not possibly be accomplished when rolling with repeaters. This meant that instead of 19 passes in the old mill we had to increase the number up to 23 when rolling a billet of 3¼ in. square down to ¼ in. oval. It is still not sure whether another two passes should have been added, if that had been possible.

The repeaters had to be assembled very exactly in the mill. Measuring by the eye was of no use; it was necessary to use gauges and fixtures. Furthermo , the guides, both entry and delivery, had to be submitted to an exact control.

The mill workers had to be taught the new work. My experience is that it is better to have new workers for a new mill than to have a crew accustomed to an old mill.

The average yield in our mill is now 93–94%, according to the size rolled. It is somewhat higher on larger sizes than on smaller.

The most common sizes rolled are rounds from 2 in. down to ¾ in. Squares and flats constitute only 10–15% of the production. On the smaller rounds the output of the mill depends on the size, because of a limited speed of 16 m./sec. in the last stand. For sizes larger than ½-in. round the output is held up by the first stand in the breakdown train, and 100–150 tons a shift is reached. A shift is 7½ hr.

Thanks to the stable modern stands and the possibility of their being exactly set, the rolling of a new size can be started, often with 10–15 new set repeater passes,

* *J. Iron Steel Inst.*, 1954, vol. 176, *April*, pp. 391–405.
† *Ibid.*, pp. 411–414.
‡ *Ibid.*, pp. 415–423.
§ *Ibid.*, pp. 406–411.

without cobbling the first bar, and the correct size can be obtained.

Mr. **T. W. Hood** (Samuel Fox and Co., Ltd.): These four papers describe essentially two unusual types of rolling-mill stand which have been developed in Sweden, and the design and operation of mills in which the technique of high-speed repeating of small sections has been successfully developed. They are of particular interest to those engaged in the production of fairly small tonnages of rods and bars in a wide range of sizes, with relatively short runs of each size, and especially to producers of special steels, for whom flexibility is of major importance.

To meet these requirements for rod rolling, there are three main types of finishing train which overcome the limitation on coil weight imposed by the speed (1400–1800 ft./min.) at which turning in can be accomplished by hand. They are as follows:

(i) Those using repeating throughout, as in these papers
(ii) Those using several pairs of tandem stands, squares being repeated from one pair to the next, and ovals being twisted within each pair
(iii) Those with a continuous finishing train, often of the vertical-horizontal type to avoid the use of twist guides.

Mills of each type have recently been installed. In Sweden, for example, the mill at S.K.F. Hofors, and the new mill at Västerås, are of type (iii) with vertical-horizontal continuous finishing trains. When I visited Hofors the mill was rolling strip, so I did not see the rod train in operation, but I understand that it works very well. Pulling between stands is avoided by looping troughs and loop lifters so that close rolling tolerances are presumably achieved. As the stands are of light and simple construction there is apparently little difference in capital cost.

Probably the main question in our minds is that of assessing the relative merits of the three types mentioned above, especially of types (i) and (iii).

Further comments on this by the authors would be welcome. The use of high-speed repeaters increases the number of parts which can give rise to trouble unless they are carefully adjusted. I would also be glad of a little more information on the actual outputs achieved, and on the percentage of cobbles, particularly for mills rolling special steels as opposed to mild steel.

It is remarkable that because of the close spacing of the stands no twist guides are required for ovals entering the repeaters. On the Fagersta mill the stands are set on wider centres; are twist guides necessary in this mill ?

In Fig. 1 of Mr. Norlindh's paper an oval is repeated and then passed through a pipe for a distance of 120 ft. from the medium-section train to the small-section train. How is a clean entry into the first stand of the small-section train achieved ?

The use of the oval-edge-oval or oval-round pass design has been favoured recently in a few plants instead of the oval-square design. This is to avoid wrinkling, particularly on material for cold heading. In Sweden oval-square is the standard design, sometimes with lighter reductions than usual. Is any difficulty experienced with this pass design ?

Roller guides figure largely in this paper. A rather similar guide has been tried at my company to overcome the difficulty of turning in by hand into the last pass after the minimum speed was increased. The results confirmed Mr. Norlindh's claim that this type of guide is very successful. Bearing life is variable because of a tendency to set the guide too tight, as the operators have been accustomed to feeling some resistance to entry with the old fixed guides.

Mr. Riddervold mentions changing complete stands with guides already set up; how long does it take to change from one size to another in the same rolls ? It is not always convenient to roll bars while the rod train is being adjusted.

In the rolling of bars in straight lengths, what tolerances are achieved in mills using the new designs of stands ? How much closer are they than in some of the older mills ?

Will Mr. Leufvén tell us what is the limited speed mentioned in connection with the multi-row cylindrical roller-bearings on the cold strip mills ?

The 4-stand tandem cold strip mill at Munkfors is of great interest. Could Mr. Leufvén give a little more information on it, particularly on the rolling speed and the tolerances achieved on thin strip ?

I would like to congratulate the authors on the originality of design and the reliability in operation of the mills described.

Mr. **R. Stewartson** (Guest Keen and Nettlefolds (South Wales) Ltd.): For those who are used to a high-speed continuous rod mill, the most striking thing about Mr. Nörlindh's mill layout is the long path of the bar from the roughing stand to the final rod stand. On Fig. 1, it would appear to be about 1000 ft. compared with 300–400 ft. in a continuous rod mill. Does such a long path result in a low finishing temperature, *i.e.*, not a variation in temperature along the bar, but an overall low finishing temperature ? If this is so, does it lead to any difficulty with the alloy steels mentioned by the author in the paper ?

In a continuous rod mill, a temperature drop of about 200° C. would be expected between the furnace and the last stand, and further cooling before coiling would be effected in the pipes by water cooling. Referring again to Fig. 1, the length of path for the last six passes, where the stock is small and liable to lose temperature fairly rapidly, is 330–340 ft., compared with 50 ft. in a six-stand continuous finishing train.

A further point about a long path in mills with fairly continuous production (as these must be, to judge by their layouts) is that there are likely to be a number of bars in the mill at one time, so that a cobble in the finishing train causes a probable loss of two or three bars, in various stages of rolling. Is this the case for the mills described ?

The authors' remarks about whip in repeaters are very much to the point, but my company have found that with a repeater between two stands, if individual drives with a fine speed-control are available, it is possible to loop at speeds up to 2000 ft./min. and keep the bar more or less within the channel, thus controlling the whip when the bar leaves the preceding stand. This effect of fine speed-control cannot be obtained when two stands are driven from the one motor, as described in the papers.

Would Mr. Riddervold say something more about his experience with fixed entry guides, since the clearances given in his paper seem somewhat tight. For the roughing stands 0·02 in. is quoted, which compares with about 0·05–0·06 in. in the U.K., a clearance which allows for any distortion in the bar, such as thick front ends.

In Table IV of Mr. Pihlblad's paper some interesting rates of groove wear in the rod-mill finishing train are given. There is a wide variation in wear for the square grooves, whereas the ovals remain more or less constant. How does the wear in these passes compare with the percentage reduction ? In the finishing train of a continuous rod mill with oval-round reduction, 0·01-in. wear for 70 tons of material rolled would be expected in the

last stand, with improved wear further back in the train, particularly in the ovals.

Reference is made to a rolling tolerance of ± 0·004 in. Does that apply to all dimensions round the bar, or merely to the two orthogonal diameters (horizontally across the gap and vertically over the depth of the grooves) excluding the shoulders, *i.e.*, the diagonal dimension of the bar ? The acceptable tolerance in the U.K. is often taken over the two orthogonal diameters only.

Do the authors consider that their close tolerance is related to pass life ? It is possible to roll high-carbon rod of 5 mm. dia. to within ± 0·004 in. or even to ± 0·003 in. on a continuous rod mill if one is prepared to change passes fairly frequently, say after 50 tons per strand compared with a life of just over 100 tons (*i.e.*, one shift's production) for the normal tolerance of ± 0·005 in. What is the pass life in the finishing stand at Fagersta when rolling to close tolerances ?

Mr. **W. Craig** (Davy and United Engineering Co., Ltd.): The mechanical details shown in the papers by sketches and photographs are of particular interest and demonstrate very successfully the ingenuity of Swedish designers. Figure 14 in Mr. Norlindh's paper illustrates an excellent design of articulated spindle end. The S.K.F. pressure-oil method is used for mounting the box so that this part can easily and quickly be removed from the roll or pinion end. The lubricating arrangements are also good and one would expect reasonably long life from the universal elements of the coupling joint. It is interesting to note that this universal spindle is highly commended by Pihlblad and Riddervold as a successful feature on their mills.

The S.K.F. pressure-oil method of mounting is given much prominence in Mr. Leufvén's paper, and it is obvious that for easy removal, bearings and coupling boxes should be mounted on a tapered seating as shown in Fig. 4. There is, however, an example shown in Fig. 23 where the bearing is mounted on a parallel seating. Is it possible to dismantle the bearing in this example by the oil-injection method ?

Mr. **N. D. Thomson** (United Steel Companies Limited): The new stand design described by Mr. Norlindh is particularly interesting to people who have to revamp an old mill in a confined site, owing to the very small space occupied. Mr. Riddervold said that in his mill he used to have six stands across the bay, but he now has 12. That would be a great boon for some of our small re-rolling mills. Mr. Norlindh's new design makes an old design look laughable from the size point of view as the slide shows, but one is a robust rough casting and the other is a smaller job machined all over. In terms of cost it would be interesting to know how the comparison works out. Is the increased cost per ton of the new design more than compensated for by the reduction in weight ?

Mr. Hood asked whether twist guides were needed for operation of the repeaters. From Mr. Norlindh's paper we get a hint (p. 396) that although twist guides are not used on small orders, with large orders they are used. Could the author confirm this ?

We have seen an excellent design of roller entry guide which has proved itself in practice on various sizes all over Scandinavia, but there are other types with two or three pairs of rollers. Most engineers who advocate the use of roller guides have to make a decision as to which to recommend for a particular job. Mr. Norlindh's design of guide has the advantage that it will reach nearer to the actual roll bite than the other types, but against this the bearings are necessarily smaller and their life reduced. Since the smaller rolled products are more flexible and more difficult to prevent falling over, one would expect that the greatest advantage of the Swedish guide over the other type lies mainly for those sizes.

Mr. Riddervold said that his yield on small products was about 93%. In a continuous rod mill in the U.K. we should expect approximately 96%. That difference of 3% on a mill rolling, say, 150,000 tons/year represents about 4500 tons waste annually. If one assumes that this tonnage is due to cobbles and crop ends, it has borne the full cost of production and even if it is only mild steel, this represents a loss of over £100,000 per year. Does not that influence one's choice of a continuous train or a train with repeaters ?

I disagree with Mr. Riddervold's statement that percentage reductions in his repeating mill are similar to a continuous finishing train such as the Morgan continuous wire-rod mill. He quotes 0·263-in. dia. rounds being rolled from a 1·57-in. square billet in 18 passes in his looping mill. A common Morgan mill reduction is to 0·212-in. dia. from a 2-in. square billet in 19 passes; this is a much heavier reduction.

As it is a low-percentage reduction, why has not the opportunity been taken to use either oval-round or oval-edge-oval pass designs ? Is it because of difficulty with repeaters and guides ?

Mr. Riddervold also states that he does not think one can roll high-tolerance products in a continuous mill. Could he please quote his figures of tolerance normally obtained so that we can compare the repeating mill with the continuous type ?

The layout of the Fagersta mill given in Mr. Pihlblad's paper shows the repeaters being operated in the opposite way to that which Mr. Norlindh recommends on p. 397. Perhaps the answer is that Mr. Norlindh's recommendation is based on Fagersta experience ?

Multiple cutting of rod-mill finishing-train rolls, as shown in Fig. 2 on p. 413, is practised also in Germany and Holland. It offers a reduction in the machining costs and it is surprising that it is not widely practised in the U.K.

We must all thank S.K.F. for the oil-injection system of mounting, which I am sure all engineers will use more and more. The tapered seat allows the system to be used for both mounting and withdrawal, whereas with the parallel neck a different system, such as heated oil, has to be used for mounting.

Is Mr. Leufvén able to quote figures of accuracy obtained in pre-stressed stands as compared with modern conventional stands ? It would be interesting to know if the pre-stressing principle results in substantial improvement in tolerance. Is the cost of a pre-stressed stand much more than that of a conventional one ?

We should perhaps think of these Swedish mill designs especially in terms of the ' Sheffield trade ' type of mill, where small quantities of various sizes and high quality are rolled. These layouts give that versatility and also high speed which enables big coils to be rolled with the minimum temperature variation from back to front end. The roller guides will assist in maintaining quality of surface finish.

Mr. **M. Langen** (Loewy Engineering Co., Ltd.): Mr Norlindh mentions that he starts repeating in the medium. mill with an oval rolled from a 2-in. square. I believe that for the higher grades of steel, especially for stainless steels, the section which is repeated is usually limited to 1¼-in. square because of the stiffness of the material. It would be interesting to hear whether Mr. Norlindh has encountered any difficulties in this respect when rolling certain grades of steel.

Is it advisable to equip repeaters with rollers so as to avoid friction and therefore scratching of the bar ?

I notice that in No. 5 stand of the medium-section mill a 0·62-in. square is rolled with rolls of 21·6-in. dia. In No. 3 stand of the small-section mill a 0·386-in. square is rolled on rolls with an 18·9-in. diameter. Do such unusually big roll diameters for comparatively small sections affect the pass design, and does the greater spread limit the amount of reduction ?

The stands in the small-section mill which are driven from one motor have a difference in roll diameter of over 2 in. so as to avoid too big a loop. With a normal pinion stand the spindle inclination might be too big for the comparatively high speeds, and I therefore presume that special pinion stands are used. Is this correct ?

The distance between stand No. 19 of the rod mill and the coilers is considerable. Can the coilers pull the rod out of the guide tubes when it has left the stand, or are pinch rolls in front of the coilers required ? If so, has any marking of the rod been experienced ?

Mr. **M. J. den Ouden** (Koninklijke Nederlandsche Staalfabrieken v/h. J. M. de Muinck Keizer, Utrecht): When we visited the Morgårdshammar mills, we saw no cobbles. Various dimensions can be rolled; we have seen this type of mill in Denmark rolling 10 mm. round at a speed of 16 m./sec.

This mill had been working for only 2½ weeks with the new installations, but there were no cobbles during the few hours of our visit.

No arrangements were made for protective shields, but people were not worried about walking behind the repeaters and the operators were convinced that there would be no cobbles during repeating. In continuous mills there is a shield as a protection.

During our visit to Kanthal they were rolling 16 mm. round on the cooling bed for making bolts. The tolerances which we saw were less than 0·1 mm. or 0·004 in.

They were able to roll 85 mm. round to 7 mm. round.

Normally one cannot reach a conclusion about new rolling methods after a visit of only a few hours, but the stands work very satisfactorily. No special men were required to arrange the stands; the work was done by the normal men, who were specialized in fitting the bearings.

AUTHOR'S REPLY

Mr. **Riddervold** (Christiania Spigerverk) wrote : Mr. Hood asks about cobbles. The number of these depends mainly on whether the billets are sound or not. Pipe-billets and bad de-seamed billets work very poorly. In our company we have no experience of special steel, but on plain carbon steel the repeaters work more safely with higher carbon content.

With regard to the pass design, both oval-square and oval-round are rolled very easily in repeaters. The oval-edge-oval design may cause some difficulties in the oval repeater, if the edge-oval is not twisted down before entering the oval pass.

Mr. Hood also asks about the time for size changing. This, of course, depends on how many stands are to be reset. As an example, I would say that changing size and resetting six stands would take about ¾ hr. from cease-rolling of the first to rolling at full speed the next.

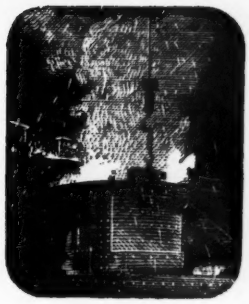
Both Mr. Hood and Mr. Thomson ask what tolerances can be attained. This depends on the size rolled. For ¼-in. round we can reach a tolerance of 0·002–0·003 in. but normally this is not required, which is fortunate, as it means that we are forced to change grooves very frequently. For smaller sizes the requirement is normally 0·007–0·008 in., and this is attained more easily than in a continuous mill.

To the question from Mr. Stewartson about clearances in fixed entry guides, I would answer that 0·02 in. is quite satisfactory because both guide and housing are machined. On the other hand, the clearance between the bar and the guide has to be larger, about 0·04–0·06 in., as stated in the paper.

To Mr. Thomson's disagreement about reductions I would say that the present reduction in our mill is somewhat lower than in the Morgan mill, because of the large roll diameter in some of the stands, resulting from the number of motors in the mill being only two. In a mill with two stands per motor the reduction can be increased to what is usual in a Morgan mill.

[Written replies from Mr. **Norlindh,** Mr. **Leufvén,** and Mr. **Pihlblad** will be published in the November *Journal.*]

AFFILIATED LOCAL SOCIETIES



CLEVELAND INSTITUTION OF ENGINEERS

Flame Radiation and Open-Hearth Productivity

By M. W. Thring, M.A., F.Inst.F., F.Inst.P.

SYNOPSIS

Equal fractional changes in heat transfer and chemical conditions produce about equal changes in overall output of the O.H. furnace. Once the bath is flat more than 90% of the heat transfer must be by radiation. These two facts make the study of flame radiation of great importance in raising O.H. productivity. The experiments carried out at Ymuiden in a specially designed furnace have shown that the length of a turbulent jet diffusion flame such as is used in the O.H. is governed by the distance to entrain the combustion air, and have related this to the jet momentum and hence the fuel or atomizing-agent pressure. With oil flames, accelerating the mixing greatly reduces the luminosity, while coke-oven gas flames are non-luminous at all lengths. Calculating the effects on the O.H. of applying the types of flame which the Ymuiden experiments have shown to be possible has shown that high emissivity is desirable even if it can only be obtained by delayed combustion. 947

OBJECTIVES OF O.H. FURNACE RESEARCH

It is usual nowadays to define productivity by the number of tons of finished material produced per unit of input, which may be (i) one hour's operation of one furnace, (ii) one ton of standard fuel, (iii) one man-hour of labour, or (iv) one ton of furnace brickwork consumed. So long as the manning of an O.H. furnace is fixed, the first and third of these are equivalent and any increase in the number of tons of steel made per furnace-hour corresponds directly to the increase in the number of tons of steel made per man-hour. The criteria of productivity of an O.H. furnace can, therefore, be reduced to the following:

(i) Tons of steel per furnace-hour, which is equal to the tons of steel per charge divided by the tap-to-tap time in hours
(ii) Tons of steel per ton of fuel, which is equal to the thermal efficiency of the process multiplied by the calorific value of a ton of fuel and divided by the thermal requirements of a ton of steel
(iii) Tons of steel per ton of bricks, which is equal to the number of charges between repairs multiplied by the average weight of a charge and divided by the average weight of bricks used in a repair.

The present paper considers how far these three productivity criteria are affected by the characteristics of the flame in the furnace, and in particular its output of heat by radiation. It is, therefore, concerned with two main questions: (i) How can the flame in an O.H. furnace be controlled to give it the desired characteristics of radiation ? and (ii) What would be the ideal flame in the O.H. furnace, *i.e.*, what characteristics should be desired ? These two questions are discussed in later sections of this paper, whilst the next section considers how far flame radiation is related to the productivity criteria.

From the point of view of the charge in the furnace there are five main properties of a flame whose variation along its length matters, and it is necessary to know how these properties can be controlled by the external variables of the quality and quantity of fuel inserted, the method of inserting the fuel, the quality and quantity of air inserted, and its preheat. Each of these five properties can be treated as having a certain average value across the flame, so that it is only dependent on distance along the flame. The properties are:

(i) The mean radiant temperature along the flame (*i.e.*, how hot the flame is)
(ii) The overall emissivity or opacity of the flame (*i.e.*, how good a radiator it is)
(iii) The fraction of the fuel which is burnt by the given point (*i.e.*, how much of the combustion energy has been released)
(iv) The mean height of the flame above the bath (*i.e.*, flame position)

This paper was presented to a meeting of the Cleveland Institution of Engineers at the Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, on 11th January, 1954.

Mr. Thring is Professor of Fuel Technology at the University of Sheffield.

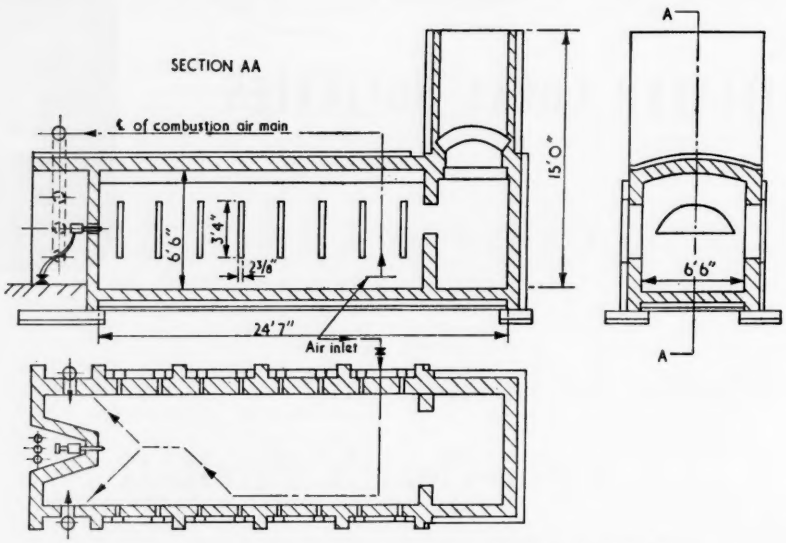


Fig. 1—Plan and elevations of experimental furnace at Ymuiden

(v) The mean width of the flame (measured in a direction parallel to the bath surface), which decides the fraction of the bath surface area covered by the flame (*i.e.*, flame shape).

HOW FAR IS FLAME RADIATION A MAIN FACTOR IN O.H. PRODUCTIVITY?

There can be no doubt that radiation from the flame in an O.H. furnace plays a large part in deciding the overall time taken to get a charge out. It is thus closely related to the first of the productivity criteria. It is even more closely related to the second one, which depends on the thermal efficiency of the process, since the greater the fraction of the energy of combustion which can be left in the combustion chamber by radiation, the greater must be the thermal efficiency of the process. The third productivity criterion depends upon flame radiation in a more negative way, in that the primary factor in the usage of refractories is excessive heat transfer from the flame to the refractories at the expense of heat transfer from the flame to the charge.

However, forced convection competes with radiation as a method of heat transfer, and the chemical side of the O.H. process competes with heat transfer as a whole in deciding the total tap-to-tap time.

How far the output of an O.H. furnace depends on chemical and how far on physical factors was studied by Robertson and the author* for the special case of a furnace of rather small bath area making very low carbon, low sulphur steel. The method was to carry out a statistical analysis on the data of about 50 casts, all of them controlled as closely as possible on a single furnace. In this case it was found that when external factors caused an increase of 10% in the rate at which the bath picked up oxygen, the time from start-charge to fully-melt decreased by 2%, but the time from start-charge to tap decreased by 4%. External variations in this rate of total oxidation explained 40% of the observed variations in the total time. When on the other hand the oxidation rate was constant, but the rate at which the furnace would accept fuel (oil) without overheating the roof was increased by 10%, the time from start-charge to fully-melt decreased by 9% and the total time from start-charge to tap decreased by 3%. These variations in the rate at which the furnace would accept oil during the melting period only accounted for about 6% in the total variations in the total time from start-charge to tap. Thus, on the furnace studied external variation of the kind of scrap, the way the scrap was charged, and the behaviour of the lime were not sufficient to allow the oil-acceptance rate to change very much, and therefore under these conditions changes in the chemistry of the process produced a much bigger effect than change in the thermal conditions; but on the other hand for equal percentage changes in thermal and chemical conditions the change in overall productivity is about equal. This means that the primary problem in studying flame radiation is how to arrange conditions in the furnace in such a way that a greater amount of radiation to the charge can be achieved without overheating the roof.

On the question of convection as a rival to radiation as a mechanism of heat transfer, it cannot be doubted that once the bath is flat, radiation must account for more than 90% of the heat transfer. Even while the scrap is piled up in the bath so that the flame is impinging sharply on it, all the experiments which have been carried out so far do not show any great increase in convection, so that radiation to the outer surface of the pile must exceed convection. There remains however the possibility that if the flame can penetrate deep inside loosely piled material, convection to the inside surface or even, for that matter, radiation to the inside surfaces—governed however by the appearance of the flame inside these surfaces where it is pushed by its high velocity—can become very important, but it is not known to what extent.

* F. L. Robertson and M. W. Thring, *J. Iron Steel Inst.*, 1949, vol. 163, pp. 31–50.

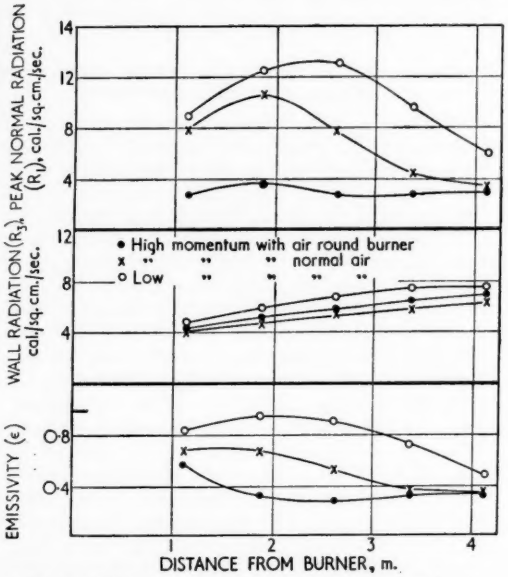

PEAK NORMAL RADIATION (R_1), cal./sq.cm./sec.
WALL RADIATION (R_3), cal./sq.cm./sec.
EMISSIVITY (ε)
• High momentum with air round burner
x " " " normal air
o Low " " " "
DISTANCE FROM BURNER, m.

Fig. 2—Effect of accelerating the mixing with oil flames

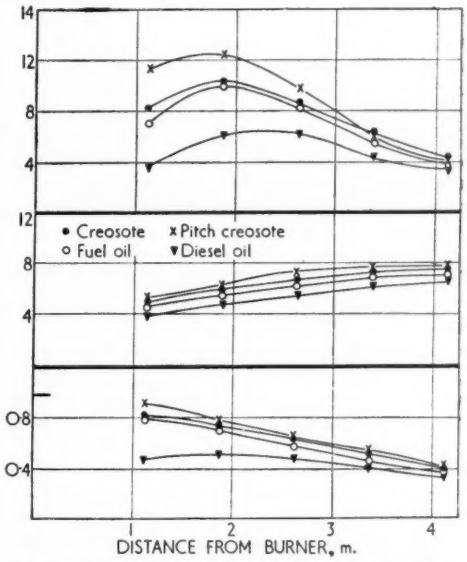


Fig. 3—Effect of changing the type of fuel when flame length is kept constant

RELATION OF INPUT VARIABLES TO FLAME RADIATION

To determine accurately the relation of input variables, such as the kind of fuel and type of burner, to the flame characteristics, it was necessary to carry out experiments on a flame which could be varied at will, and which had to be comparable in size to an O.H. furnace flame because there are scale effects which make the direct application to the O.H. furnace of results of laboratory-sized experiments impossible. Large and costly experiments burning considerable quantities of fuel without any industrial production were therefore necessary, and the means were at last found by France, England, and Holland sharing their financial and technical resources. To study the flame by itself a simplified furnace was built in which the flame flowed down the axis of a comparatively large chamber before leaving through a restricted exit where the final gas composition could be measured.* A diagram of the apparatus is shown in Fig. 1. The key measurement was the total radiation determined with a narrow-angle instrument sighted across the flame either on a hot or a cold background, so that knowing the radiation temperature of the background one could determine the mean radiant flame temperature and emissivity. This measurement could be carried out at each of five slots, spaced from 4 to 14 ft. from the burner. At each slot the instrument could be traversed vertically to give a variation of radiation across the flame.

The furnace has also been used for the study of detailed conditions within two flames by means of water-cooled probes inserted into the flame and using measurement of local velocity, gas composition, soot concentration, temperature, and radiation. In a series of trials carried out on this furnace it has been possible to determine the factors governing the combustion/distance curve and the emissivity/ and temperature/distance curves for fluid-atomized oil flames and turbulent-jet coke-oven gas flames. These are the types of flame which are used when these two fuels are fired in the O.H. furnace.

For a turbulent-jet diffusion flame, whether of fluid-atomized oil or of coke-oven gas, the mixing curve and the flame length along the furnace is controlled by the entrainment of air consequent upon the jet momentum. Thus by blowing the same amount of coke-oven gas at a higher pressure through a smaller nozzle the air necessary for combustion will be entrained in a shorter distance and the flame will liberate its heat energy in a shorter distance. For example, in the case of a jet in a very large chamber with unlimited excess air, the distance (x_t, ft.) along the axis to the point where the time-average gas composition corresponds to the theoretical combustion concentration C_t is given by

$$x_t = \frac{10 \cdot 5\ R'_0}{C_t}$$

where R'_0 is the radius in feet of the equivalent nozzle through which the fuel, or fuel plus atomizing agent, would flow at its given mass input rate and its given jet momentum, but with a density corresponding to the hot burnt gases. Thus, doubling the jet momentum would be equivalent to dividing its equivalent nozzle radius by two and thus reducing the flame length by about 30%.

This work has therefore led to the conclusion that the primary function of the atomizing agent in the O.H. furnace with an oil burner is not to atomize the oil, a purpose for which far less energy would be sufficient, but to provide jet momentum, so that the

* *J. Inst. Fuel*, 1951, vol. 24, S1–S16; *Ibid.*, 1952, vol. 25, S17–S36; *Ibid.*, 1953, vol. 26, pp. 189–224.

most efficient burner is the one which produces a given jet momentum with the least quantity of atomizing agent. Streamlining the burner and accelerating the oil droplets gently have been shown in B.I.S.R.A. work to provide a considerable increase in burner efficiency, so that it will be possible to use 30% or 40% less steam with the present jet momentum. This can provide a very great economy in steam consumption, but even more important, it will reduce the adverse effect of steam on flame radiation mentioned below.

Effect of Input Variables on Emissivity/Distance Curves

With oil flames, acceleration of the mixing of the combustion air with the flame by increasing the jet momentum brings the flame emissivity down correspondingly earlier. When the mixing is accelerated still more by bringing the whole of the combustion air in through a tube, luminosity almost completely disappears (Fig. 2). The effect of changing the type of fuel when the flame length is kept constant is shown in Fig. 3, from which it will be seen that heavy pitch creosote gives the highest emissivity in the early part of the flame, followed by creosote, then heavy fuel oil, then diesel oil. Lower than all these is coke-oven gas (not shown in Fig. 3), which is almost completely non-luminous in a turbulent flame of this type. At the tail of the flame when combustion is complete all the fuels give an emissivity corresponding to the non-luminous radiation of carbon dioxide and water vapour. When various mixtures of oil and coke-oven gas are used the replacement of 20% of the coke-oven gas by oil gives an increase to about 60% (*i.e.*, of 0·3–0·5) of the emissivity in the early part of the flame, while a replacement of 75–80% of the coke-oven gas by oil gives the same emissivity as is obtained with 100% oil.

When flames of heavy fuel oil with air and steam atomization are compared, it is first necessary to correct for any differences in the jet momentum. When this is done it is then found that the air-atomized flame gives an appreciably higher radiation in the early part owing to the existence of both a higher temperature and a higher emissivity with the air-atomized flame in the early part.

Apart from differences of efficiency in producing jet momentum resulting from variations in the energy of the steam fed to them, there are no great differences between different steam-atomized oil burners, probably because they all produce droplets sufficiently fine to be evaporated before they are mixed with enough air for combustion. Compared with a fluid-atomized burner, a pressure-jet burner gives a lower emissivity on the axis but a shorter flame, which spreads more widely at the early part.

Future work on the international flame-radiation furnace at Ymuiden will include a study of the effect of air preheat on flame radiation, a study of the possibility of burning pure coke-oven gas in such a way as to give a luminous flame, and the study of producer-gas flames, made both in a conventional producer and in a double-draught producer. With regard to the second study, experiments elsewhere, on preheating the gas to a temperature where the methane is decomposed, and on allowing the gas to burn partially with an air deficiency before complete combustion, have indicated possibilities on these lines.

EFFECTS OF FLAME-RADIATION CHARACTERISTICS ON PRODUCTIVITY

Ultimately it is hoped to be able to vary in an operating O.H. furnace the external variables shown by the Ymuiden work to have the greatest effect on the flame-radiation properties, and to determine directly their effect on productivity. Until this can be done, however, the best method available is to set up a theoretical model of the O.H. furnace on which to calculate the effects of the changes. Such a procedure has been carried out.* The flame was assumed to be a thin sheet over the surface of the bath, spreading from a point at one end to the full width of the furnace at the other. Four flames were considered.

In flame 1 the emissivity of the thin flame was unity for the first sixth of the furnace, and fell steadily to 0·1 in the next sixth, where it remained for the remainder of the furnace. In this flame combustion was assumed to take place uniformly in the first third of the furnace, and to be complete thereafter. This flame would correspond to a real oil flame with very rapid combustion and a very short flame length.

In flame 2 combustion was similar to that in the first, in that it was to be complete after a third of the flame length, but the emissivity was supposed to remain at unity throughout the length of the flame. This would correspond to an ideal flame, not yet achieved, in which means would be found of retaining a high emissivity after combustion is complete.

In flame 3 combustion takes place uniformly over the whole length of the furnace, but the emissivity falls to 0·1 at a third of the length along the furnace as in flame 1. This might correspond to a coke-oven gas flame with rather low jet momentum, and similarly slow combustion coupled with a low emissivity.

In flame 4 combustion takes place uniformly along the length of the furnace but the emissivity remains high at 1·0 over the whole length. This might correspond to an oil or pitch-creosote flame with a very low jet momentum.

By neglecting longitudinal radiation and carrying out a heat balance for the roof, the flame, and the steel in each of these successive zones along the furnace, it was possible to solve simultaneous equations to determine the change in flame temperature for each section, the mean roof temperature, and the net heat flowing to the steel. Calculation was carried out for infinite fuel-input rate, *i.e.*, the case when the flame is not cooled by heat transfer to the roof and the walls at all, and for finite fuel-input rates of 4000, 2000, and 1000 lb./hr. of oil to a 100-ton furnace with a bath area of 588 sq. ft.

The calculation showed that with the two flames with rapid combustion, high-peak temperatures in the roof were obtained, especially with the flame having also a high emissivity (flame 2), which gave a roof temperature of 1750° C. just before half-way along the furnace for a fuel-input rate of 4000 lb./hr. Thus for a silica roof with this type of flame, 4000 lb./hr. would be impracticable and the phenomenon

* M. W. Thring, *J. Iron Steel Inst.*, 1952, vol. 171, pp. 381–392.

of a limited oil-acceptance rate discussed previously (*see* p. 166) as an observed phenomenon appears as a result of the calculation.

By taking the amount of heat required to melt 100 tons of steel from cold metal and dividing it by the net heat-transfer rate to the steel, the times for start-charge to fully-melt for the four different flames and for different fuel-input rates can be determined, as well as the total fuel input during this period. These are given in Table I, from which it appears that the fastest melting corresponds to the high rate of fuel input and the high-emissivity, short-combustion flame (flame 2) whilst the lowest total fuel required is also found with this flame. It will also be noticed, however, that there is very little difference between the fuel required to melt 100 tons with this type of flame when the fuel-input rate is halved, although the time to melt is slightly more than double. This shows that the first and third productivity criteria are not very closely related.

If the furnace roof is of silica, so that the roof temperature must not exceed 1600° C., the calculation suggests that there are three different optimum flames during the charging, melting, and refining periods respectively. During the charging period there is cold metal on the surface and there is no danger of overheating the roof; the problem is to burn as much fuel in the furnace as possible and transfer as much of its heat to the charge as possible. Then from the point of view of radiation, flame 2 with rapid combustion which retains a high emissivity would be the best if we knew how to make it, both from the point of view of thermal efficiency and output. Flame 4 is the second-best type of flame, having high emissivity with delayed combustion.

During the second period from finished-charge to fully-melt when the bath is level, it still requires a high heat input to melt the solid material underneath. Flame 2 at the reduced-heat input rate of 2000 lb./hr. is the best for thermal efficiency, but flame 4, with the maximum fuel-input rate is the best for melting speed. The best of all would be a compromise between the two, *i.e.*, a flame for which combustion was complete after about three-quarters of the length of the furnace, so that the roof temperature was nearly uniform all along the furnace instead of rising slightly to the tail as it does with flame 4. During the refining period the function of the flame is not to pass heat into the bath, but merely to maintain the temperature along the whole length of the furnace, and for this purpose a high heat-transfer coefficient is not required and it does not matter whether the flame has a high or low emissivity, but it is important to have a long flame with delayed combustion.

Table I

PRODUCTIVITIES CALCULATED FOR THE FOUR FLAMES AT DIFFERENT FUEL-SUPPLY RATES

	Fuel-Input Rate, lb./hr.	Total Melting Time, (t_{1+3}), hr.	Oil Needed to Melt 100 tons, tons
Flame 1			
Rapid combustion, falling emissivity	4000	5·02	9·0
	2000	8·00	7·15
	1000	17·7	7·9
F'ame 2			
Rapid combustion, maintained emissivity	4000	3·15	5·6
	2000	6·73	6·0
	1000	17·3	7·7
Flame 3			
Slow combustion, falling emissivity	4000	7·88	14·1
	2000	11·8	10·5
	1000	24·4	10·9
Flame 4			
Slow combustion, maintained emissivity	4000	3·76	6·7
	2000	7·54	6·75
	1000	18·5	8·25

CONCLUSIONS

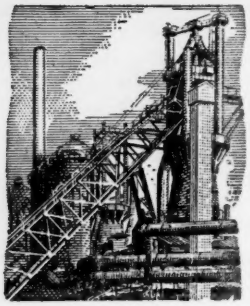
Proposals for Improving the O.H. Furnace

For steam-atomized burners burning heavy fuel oil or pitch creosote the use of a burner designed to give the greatest possible efficiency in converting the energy of the steam into jet momentum, and the use of steam with a maximum energy, would result in considerable steam saving, which in turn will result in a hotter and more strongly radiating flame. The use of the jet-momentum formula for calculating the equivalent flame lengths for alternative fuels can also be of great value.

The optimum flame length during the period when the scrap is piled up in the furnace is not yet known, and all the present indications are that increasing the jet momentum to give a shorter flame during the charging period gives an increased output, probably because of the greater oxidation rate associated with the higher-velocity flame. During the period when the bath is melted level, but not yet fully melted through, there is no doubt that the optimum flame length is the one which gives an equal roof temperature at the ingoing and outgoing ends, and a positive recommendation can, therefore, be made that furnaces should be operated with two or even three roof pyrometers, and with the flame length adjusted by adjusting the steam/oil ratio, or the free area of a coke-oven gas nozzle, to make the readings of these instruments equal.

Requirements for Further Experiments

The work at Ymuiden has shown clearly the effect on emissivity of adjusting the flame length, and of changing from one fuel to another. Experiments in the O.H. furnace are now badly needed in which these same changes are made throughout complete casts, and the effects upon the charging, melting, and refining times and the other productivity criteria are determined by accurate statistically designed methods. There is probably also no doubt that the application of oxygen meters to the waste gases of the O.H. furnace to determine the extent of air inleakage, and of suction pyrometers to measure preheat temperatures, will be of great use in practice. When the O.H. plant is as well instrumented as the corresponding plant at an oil refinery, and as air-tight as a gas-turbine combustion chamber, the fuel technologists will have done their work, and will turn with a clear conscience to developing new processes such as continuous steel making.



IRON AND STEELWORKS ENGINEERING

THE IRON AND STEEL ENGINEERS GROUP

THE IRON AND STEEL ENGINEERS GROUP

REPORT OF THE TWENTY-FIFTH MEETING

THE TWENTY-FIFTH MEETING OF THE IRON AND STEEL ENGINEERS GROUP of The Iron and Steel Institute was held at 4 Grosvenor Gardens, London, S.W.1, on Thursday, 18th March, 1954. Mr. C. H. T. WILLIAMS (The Park Gate Iron and Steel Co., Ltd.), Chairman of the Group, occupied the Chair.

At the MORNING SESSION, a paper by Mr. A. J. LAMB and Mr. A. H. WADDINGTON (Paterson Engineering Co., Ltd.), entitled " Treatment of Water for the Iron and Steel Industry," was presented and discussed.

At the AFTERNOON SESSION, the paper presented and discussed was " Modern Industrial Boiler Plant," by Mr. W. P. C. UNGOED (Steel Company of Wales, Ltd.).

PROCEEDINGS OF THE MORNING SESSION: 10.30 A.M. to 12.45 P.M.

Discussion on the Paper—

TREATMENT OF WATER FOR THE IRON AND STEEL INDUSTRY*

Mr. **A. J. Lamb** (Paterson Engineering Co., Ltd.) presented the paper.

Mr. **A. H. Waddington** (Paterson Engineering Co., Ltd.), who also took part in the presentation of the paper, said: Water is often one of industry's most important and cheapest raw materials, but all too often its treatment and use receive little scientific consideration. Modern water-treatment plant is in essentials much the same as it was 20 years ago. The aim of the modern designer, however, is to pay much more attention to the preparation of the water before filtration. In this he has been aided by the greater knowledge which water chemists have gained of the interaction of the various water-treatment chemicals and the better understanding of the mechanism of coagulation. This has resulted in the introduction of various coagulants and coagulant aids which enable the plant operator to maintain a consistent quality of final water despite the variation in the nature of the source of the raw water.

The greater use of synthetic detergents is complicating the purification of river-derived supplies, which often receive high concentrations of detergents from factories and sewage works, rendering treatment very difficult.

Two substances used for the clarification of water have been omitted in the paper, namely the two pickling effluents, one which has a sulphuric-acid base and the other a hydrochloric-acid base. In many works these effluents may contain 15–20% of ferrous sulphate or ferric chloride, but unfortunately they are highly acidic. Nevertheless, in certain circumstances, provided that they can be readily transported to the waterworks plant, their use should be considered. It may be found, on examining costs and having regard to the necessity for suitably neutralizing any excess acid, the overall cost of these will not be justified. On the other hand, most alkalis, such as lime or chalk, are relatively cheap and are often available at the works for the treatment of these effluents before disposal, so that in many works their use may prove practicable. It may not be desirable or feasible to use them entirely, to the exclusion of the better-known and purer coagulants, but on the other hand it should be possible to use them in part, and in some cases the acidity which they carry should prove valuable rather than detrimental.

Mr. Waddington then read the following written contribution from Mr. **J. Samuel** (Unifloc, Ltd.): The conditioning of water for the iron and steel industries, and for all other industries, is becoming more important every day. As the authors point out, this is due to the

* *J. Iron Steel Inst.*, 1954, vol. 176, Mar., pp. 291–302.

high cost of municipal supplies and to the pollution of so many natural supplies.

In all cases of water treatment, serious consideration should be given to methods of recirculation, using suitable purification processes where applicable. In particular cases, such as cooling water in wire-drawing mills, slab descaling, and water used in the recovery of furnace flue dust, plants installed by my company are using continuous recirculation methods with flocculation and filtration aids. Make-up water, in at least one case, is obtained by using rain-water from the roofs of adjoining buildings. Such methods are trebly advantageous, giving economy in the use of water, freedom from effluent problems, and the recovery of valuable products. In many instances the use of such methods proves less costly and troublesome than the continuous purification of an already polluted source. Water used for cooling purposes can be treated in the same way. The initial removal of temporary hardness, with suitable treatments such as flocculation and/or filtration during recirculation, and the provision of a small bleed to waste to control the concentration of soluble salts, ensures a satisfactory water at a far more economical figure.

The authors have referred to such flocculating chemicals as aluminium sulphate, activated silica, sodium aluminate, etc., but they seem to have overlooked a very important class, the starch–salt type, now extensively used for rapid flocculation in many industries, including the iron and steel industry. The class of flocculants referred to in the paper is not very effective for the flocculation of colloidal or semi-colloidal mill-scale, blast-furnace flue dusts, or coal-clay dispersions, present in a large number of streams. In most cases flocculation does not take place, or is very slow. The flocs, if formed, are fragile, and, as the authors state, require 15–30 min. pre-agitation to build up. Where the amount of water undergoing treatment is high (*e.g.*, 100,000–200,000 gal./hr.) a very large tank, apart from the actual settling vessel, is required. When using a starch–salt type flocculant, this pre-agitation time is unnecessary. The concentration of this flocculant under average conditions is 5–10 p.p.m.

The authors very correctly emphasize the importance of removing dissolved oxygen from boiler water used in high-pressure boilers. In view of recent trends and opinions, the removal of dissolved CO_2 should also be aimed at. In a recent international discussion much emphasis was laid on the corrosive effects of dissolved CO_2 in high-pressure equipment. I recently investigated a case of corrosion in high-pressure heat exchangers. The findings indicated corrosion with CO_2, aggravated by a little dissolved oxygen, as follows:

(1) $Fe + 2H_2O + 2CO_2 = Fe(HCO_3)_2 + H_2$
(2) $Fe(HCO_3)_2 = Fe(OH)_2 + 2CO_2$
(3) $2Fe(OH)_2 + O = Fe_2O_3.H_2O + H_2O$
(4) $Fe_2O_3.H_2O + Fe = Fe_3O_4 + H_2$.

More care is needed than is very often shown in the use of zeolite base-exchange softening. Natural waters, containing temporary hardness and very often sodium bicarbonate, are treated with zeolite without previous partial treatment. Such treatment gives a water of high bicarbonate alkalinity, decomposing to liberate CO_2 in evaporators and boilers. Tests have also shown that it is not sufficient to convert sodium bicarbonate to carbonate in advance of the evaporators or boilers, as some carbonate also decomposes to liberate CO_2. In such cases, removal of sodium bicarbonate and carbonate must be carried out by precipitation as calcium carbonate outside the zeolite plant.

Mr. Waddington: I cannot agree with Mr. Samuel's remark that the normal coagulants mentioned in the paper are not satisfactory for the types of dispersion and colloidal or semi-colloidal materials mentioned, but I do agree that such dispersion as flue dust, mill-scale, and fine coal can be effectively coagulated by the use of the starch–salt preparations. However, they are not more effective than the judicious use of lime in conjunction with activated silica. We are installing a number of large plants in gold mines in South Africa, in which the very fine dust obtained in these mines is being precipitated by a process using lime and activated silica.

In connection with the various mechanical improvements incorporated in modern plants, it cannot be too strongly emphasized that the modern treatment-plant designer regards the plant as a whole and very definitely aims at making each part of the plant as effective as possible, at the same time ensuring flexibility. Another factor in modern plant is that manual control is now reduced to a minimum, and so mechanically or hydraulically operated valves and control tables are used in conjunction with loss of head and rate of flow gauges, and even in some cases with recording instruments for certain physical and chemical characteristics of the water. These bring about marked economy not only in the expenditure on chemical treatment but also in the percentage of waste water and in the power consumed for the operation of pumps and air blowers for filter cleansing.

Mr. **N. H. Turner** (Appleby-Frodingham Steel Co.): It has been said of water that it is such a cheap commodity that nobody pays attention to it until there is a shortage. This attitude has tended to change lately as it has become more fully realized that, although an amount of water is available whose average does not change much from century to century, the requirements of the population and of industry are increasing rapidly, and the need for a policy of conservation is becoming more apparent. Conservation implies treatment, either in the initial stage of the utilization or at least before the water can be returned in whole or in part to the river from which it may have been originally obtained, if the latest regulations on river pollution are properly observed.

I therefore read the paper with great pleasure, even though the authors seem to be more at home with the treatment of water than with its utilization in iron and steel works. The list given on p. 292 ignores, among other things, the blast-furnaces and ancillary services, which are probably the largest consumers in iron and steel works, and which are often responsible for a large proportion of the difficulties experienced by the works water engineer. The rehardening of the softened water used in a blast-furnace gas-cleaning plant, for instance, where the water has to be recirculated, may be responsible for more deposition than would have come out of the original water after treatment.

In referring to sources of water, the authors say that the municipal supply cannot be used because it is not feasible or economical to do so. There is, however, one form in which the municipal supply can still be used, by obtaining it at the outlet of the sewage works. We have done that at Appleby-Frodingham: we have had some trouble (a certain amount of foam at one time caused difficulty), but this is one way of making use of water which otherwise goes to waste.

I found no reference in the paper to instruments which make it possible to record the extent to which water treatment has been carried out properly. On the question of clarification, the authors say that coagulation and sedimentation should produce water having a turbidity of not more than 20 p.p.m. This is evidently a question of economics; for certain purposes it is imperative that

clarification should reach that level, but for other purposes more latitude may be allowed.

The use of the open filter is nominally ideal, as the low head available causes a low velocity through the bed, with a consequently better chance of removing suspended matter. On the other hand, the ground area occupied is very large and cannot always be afforded. In such a case pressure filters have to be used, and there is no reason why, when the filter bed is properly graded, they should not be made to give the desired results.

On the subjects of filters, what is the authors' opinion on the relative merits of anthracite as compared with sand as a filtering medium ?

The authors recommend chlorination as a means of disposing of algæ, which is quite effective, but since it is not selective care has to be taken when the treatment of the water is partly biological that the useful bacteria are not destroyed. Algæ can sometimes be made use of for removing some of the temporary hardness, and we are hoping at Appleby-Frodingham to take advantage of it in the treatment of the sewage effluent used. Where we have reason to inhibit the growth of algæ, we store the water in reservoirs where light does not penetrate.

The paper suggests that there is no hard and fast rule for the choice of coagulant. It is, however, known that certain coagulants are unsuitable for water deficient in certain constituents, and perhaps a ' rule of thumb ' could be developed as a rough guide.

The paper regrettably does not sufficiently emphasize the need for water economy. Even in those works which are not faced with the need to obtain their water supply from a distance, suitable treatment should permit a more efficient and economical use of the water. At Appleby-Frodingham the present consumption is about 6 tons of water per ton of ingot made, but we are not satisfied that we have necessarily reached the minimum.

Mr. **Lamb**: I do not think that the treatment of water required at blast-furnaces would differ from that referred to in the paper. Sewage effluent has been used in a number of cases; one power station near London uses it as make-up for the cooling circuit; they merely settle and filter it, without any chemical treatment.

Instrumentation on water-treatment plant was thought to be beyond the scope of the paper.

The area required for an open filter is not larger than that for a pressure filter. Both pressure and gravity filters for industrial purposes operate at about 100 gal. per sq. ft. per hr., and the area required is the same. In many instances gravity filters can be incorporated much more easily than pressure filters; the size can be altered much more readily, and they can be made longer and narrower. Pressure filters are restricted, however, to circular filters, either vertical or horizontal. Most industrial water-treatment plants, apart from steelworks, are of the gravity type, which is commonly used, except where it is desired to pump water from the source and not pump again; in this case pressure filters have to be used. I prefer to use gravity filters where possible.

We have used both anthracite and sand in filters. In 1927 anthracite was first used in filters on an oil eliminator, the main object being to prevent the absorption of silica, which might occur if sand were used. It was not used to any great extent on plant, but the Americans boosted the use of anthracite as having greater advantages than sand. The two have been compared in a battery of filters, but exhaustive tests showed that there is very little difference in the result. With anthracite a slightly longer filter run may be obtained, but even that is not definite.

I agree that if it is possible to store the water in a closed reservoir it prevents the growth of algæ, but if the water is passed through a circuit where the temperature is raised there will still be the possibility of algæ forming in the circuit. In most instances it is not possible to have a closed storage tank large enough to store sufficient water.

Mr. **Waddington**: Instruments for the control of final water are limited in most plants to *p*H recorders and automatic residual-chlorine records. The *p*H instrument can also be used for the control of lime dosage. For instance, in treating the effluent from a fullers'-earth works which had to be sedimented by the addition of lime in a highly acid and variable effluent, the lime dose was controlled by a *p*H recorder.

In the municipal field, efforts have been made to perfect a continuously recording turbidity meter and colorimeter. There is no instrument of this type on the market at present which is 100% efficient. Instruments are available for manual use for turbidity and colour measurement, and it is usually on these two points that the quality of the final water is judged. The question of turbidity is receiving considerable attention, and it may not be very long before an instrument is available that is capable not only of indicating when the filter bed is breaking and the first turbidity will come through, but also of indicating when sufficient wash water has been used in the filter so that the filter is always washed to the same degree of cleanliness.

I assume that in referring to a turbidity of 20 p.p.m., Mr. Turner had in mind our remark that water with a turbidity of not more than 20 p.p.m. after sedimentation was suitable for filtration. That is a very safe figure; I would not suggest going above 20 p.p.m. for direct filtration. In the sludge-recirculation plant illustrated in the paper, by settlement only the water leaving that tank will often have a turbidity as low as 5 p.p.m., and there have been one or two installations (although we do not recommend this) where the water has been passed direct to process use without filtration.

In connection with the choice between the so-called gravity filter and the pressure filter, the gravity filter is usually desirable where water has to be pre-treated by settlement and chemical addition, because it makes re-pumping unnecessary. It is useless to condition water and have it leaving the sedimentation tank carrying a certain amount of floc, and then be obliged to break that floc before going on to pressure filters; if that is done the results will be inferior to those obtained by the sedimentation tank and gravity scheme without pumping.

I was very surprised that Mr. Turner considers some bacteria to be useful. Chlorination, unfortunately, is not selective, and its use kills all the bacteria and produces virtual sterility. The growth of algæ in the light, in open reservoirs, is not uncommon, and we have had trouble with some filters in which algæ have grown on top of the filter. That has been very largely prevented by replacing the ordinary lighting with blue glass; a blue glass roof will prevent algæ from growing.

I wish that I could formulate some hard and fast rules for the choice of coagulants in relation to various types of water. In one case where this was attempted, after considering the analysis I discussed the treatment of this particular well supply. The analyst compared the sample from the well with a number of bottles which he had labelled 1–20 purely by eye; he assumed that because there was some similarity the treatment which had been successful in the case of the water chosen would also be effective in the case under consideration.

There are, however, certain rules that can be given. For instance, soft moorland waters are usually acidic and contain peat colour and turbidity; they will coagulate best at a *p*H of 4·8–5·8. To do that sufficient coagulant (such as alum) must be used to remove colour. In

addition, those waters are very soft; they usually have an alkalinity of 15–20 p.p.m. at the most, and so an alkali must be added. Lime is the usual choice, but the alternative is chalk, which is much safer. It is only sparingly soluble, whereas lime is very soluble, and the dose required is only 3–5 p.p.m. If more is added the colour is redissolved, and over-dosage with lime is fraught with considerable danger. I have seen waters leaving filters improperly treated where the colour of the final water has been greater than that of the original.

There are other types where a large amount of mineral or colloidal matter is precipitated, and in such cases iron coagulants can be used, or alum with or without sodium aluminate. Alternatively, activated silica can be used. With a river-derived supply it can be said that if 2 grains of alum per gal. are used for a colour of, say, 25–40 p.p.m., for every 25–30 p.p.m. increase in colour, 1 grain of additional alum will be needed. As the turbidity increases for every 50 p.p.m. of turbidity, the coagulant dose will have to be increased by roughly 0·5 grains/gal.

Mr. **N. H. Turner**: I can remember sodium aluminate being used as a coagulant with success in one neighbouring works, but with no success whatever by us. The basic reason was that the water in the first case came from strata containing dolomite, whereas ours did not contain any magnesia.

Mr. **Waddington**: Sodium aluminate definitely functions better in the presence of high magnesia, and in softening plants in many cases (lime precipitation plants) the makers of sodium aluminate recommend the addition of magnesium sulphate to provide magnesium aluminate floc. In other cases magnesia or dolomite is used for the removal of silica from water, and particularly water for boiler-feed purposes. In Germany, for instance, the first treatment of the water is about 20 min. agitation with a mixed magnesium–calcium oxide (a calcined dolomite), which reduces the silica to less than 3 p.p.m.

Mr. **T. H. Turner** (British Railways): My especial interest in water-treatment arose in 1930, when I joined the old L. and N.E. Railway, where there was much boiler trouble, due to corrosion of steel and copper, the deposition of boiler scale, and the concentration of the boiler-water solids. For almost every use of water in a steelworks it will be necessary to consider those three aspects when dealing with the suitability of a water-treatment system. Whatever the reason for water treatment, water will nearly always come into contact with metal somewhere, so that metallurgy is involved, in addition to chemistry and engineering.

Mr. Waddington has dealt with one type of tool—water softeners, filter plants, etc.—but there are also mental tools, which are needed as well. When I began to deal with this problem, hardness was evaluated in seven different ways. The English and American figures differed because the gallons were different; the Russians had a different system from the Germans, and the Germans a different system from the French. One of the first steps which had to be taken was to arrive at a standard unit of hardness; 'parts per million' was chosen.

There is now a group of five British Standard specifications covering the problem:

B.S. 1328: 1946 "Methods of Sampling used in Steam Generation"
B.S. 1427: 1949 "Tests for water used in Steam Generation" (Group *A* Control Tests)
B.S. 1170: 1947 "Treatment of water for Marine boilers"
B.S. 2455: 1954 "Methods of sampling and testing Boiler Water Deposits"
B.S. 2486: 1954 "Code for the treatment of water for Land boilers."

The first of these standards describes how to sample a water; this was published in 1946 and is now being revised. It deals with how the chemist obtains his sample. Analyses of samples taken from different points in a boiler should give different results, if they are correct. British Standard 1427 deals with tests for water used in steam generation, and should be useful for the iron and steel industry. These Group *A* control tests were designed with ships in mind, and so they had to be simple tests which could be done without a laboratory. The Group *B* tests, 41 tests in all, which have been worked out during the past five years have now been printed in first draft form.* They are more advanced tests for water, not for steam generation only but for industry generally, because they cover a much wider field than the original tests. This further B.S. will be entitled "Methods of Testing Water Used in Industry."

Once the water has been sampled and analysed it must be treated. The boiler corrosion problem arose as a war emergency; it was causing a great deal of trouble in ships, owing to the convoy system, which meant that the boilers had to be kept continuously in steam, and so something had to be done quickly. British Standard 1170 was therefore produced; that was revised as soon as peace was restored, and recent advances are being incorporated in a second revision, now in progress. This document has become used for training marine engineers, and is the bible for water treatment for merchant vessels. The Admiralty use a similar system, but have their own specifications.

One of the chief problems is scale, which varies in different parts of the boiler equipment, and is one reason for treating the water. A further British Standard, now in the press, deals with methods of sampling and testing boiler-water deposits. It couples the sampling and the testing, and it means that an engineer will in future be able to obtain an analysis from the chemist in the same terms and in the same order, so that he can compare one scale very easily with another.

The most recent standard, also in the press, is a code of water treatment for land boilers. So far as possible it follows the same lines as that for marine boilers; however, land waters are more varied than sea waters, and many big vessels use sea-water distillate; hence the land-boiler water treatment has to be more varied.

In these specifications, and particularly in the last one, there is a glossary of terms. If the iron and steel industry when speaking of its water problems will use those standard terms, they will find it very helpful. The present authors on the first page of their paper speak of 'permanent (non-carbonate)' and 'temporary (carbonate)' hardness. The B.S.I., however, speak of 'alkaline' and 'non-alkaline' hardness, since they found a possible ambiguity in the use of the terms 'carbonate' and 'non-carbonate' hardness. Now that the B.S.I. have decided in favour of 'alkaline' and 'non-alkaline,' the next generation of engineers will think in those terms, and also in terms of 'parts per million,' which has also been adopted as standard nomenclature.

On p. 302, the authors say that "The supervision and control of a water-treatment plant must be considered an essential," and I should like to emphasize that. I have been responsible for forty or fifty water-softening plants and had to make the water treatment pay. That is the final proof of whether it is effective.

The French Railways have 900 people on water treatment. There is no corrosion at all in their boilers while

*T. H. Turner, *Engineer*, 1954, vol. 197, June 25th, pp. 918–919.

they are in service, but only when they are being washed out or laid up. That is also true of an Admiralty or merchant vessel boiler. There is accordingly a provision in these B.S. specifications for what should be done when the plant is not in use.

Water treatment will not be effective in a steelworks unless a log-book is kept from the beginning and control is maintained, using the standard tests. That is absolutely fundamental, and in France, where the railways are making a success of boiler-water treatment for locomotives, the water is taken from every single boiler for test. It is not sufficient to rely on what the water-softening plant does; the water in the boiler or in the furnace-cooling circuit must be tested, because that is the water in contact with the metal to be controlled for scale, blowdown, or concentration, which in a steelworks may include iron oxide as well as what is normally taken into account in the case of a boiler.

Monsieur Armand, head of the French Railways, introduced a treatment called 'T.I.A.'; he emphasizes that it is necessary to deal with corrosion, scale, and blowdown together, as "a matter of faith and discipline."

Mr. **Waddington**: Mr. Lamb and I fully endorse the excellent remarks which Mr. Turner has made.

The second edition of "Approved Methods for the Physical and Chemical Examination of Water," issued by the Institution of Water Engineers, is in line with the publications referred to by Mr. Turner. It relates more particularly to drinking water; it now uses 'parts per million,' instead of 'parts per hundred thousand,' and indicates the exact way of reporting and designating the various tests. It still, however, retains the old nomenclature of 'carbonate' and 'non-carbonate' hardness.

Keeping a log-book is very important and can prove most useful. I agree that the French Railways' 'T.I.A.' process is very useful.

Mr. **E. L. Streatfield** (Houseman and Thompson, Ltd.): As a worker in the field of water treatment for many years, I find this a very interesting and well-balanced paper. The subject is very large, but the authors have succeeded in highlighting the most important points in the design and control of plant.

A correction is necessary on p. 292, where the authors deal with the effect of heated surfaces on a water containing temporary hardness; they say that precipitation might take place and it "might be non-corrosive." I think they mean that it would be corrosive, by the liberation of CO_2.

Dealing with the automatic apportioning of chemicals used in water treatment, I strongly support the authors' contention that it is better to provide if possible ample storage to balance out variations of rate of flow, thus keeping constant dosage. The equipments available are excellent, but these are sometimes taken to limits for which they were not designed. With very low rates of dosage many problems arise, such as settling-out of precipitates from milk of lime. It is undesirable to stretch the control outside the intended range.

Dry feeders are on the whole a nuisance, owing to the problem of feeding a powder. When dealing with chalk or aluminium sulphate, if there is moisture present (as there is bound to be) there is the risk of caking and of bridging in the hoppers feeding the equipment. Solution feeding is the best method and should be adopted wherever possible. Dry feeders are often popular abroad, but the desire to install them should be resisted wherever possible.

The old horizontal straight-pass type of sedimentation tank shown in the paper is (or ought to be) going out of use, because many investigators have shown that in large bodies of water where there is horizontal flow the temperature effects are very pronounced and the available retention volume of the tank is not fully used. Up-flow tanks are therefore preferable, with or without sludge blankets. So long as a final up-flow velocity of about 0·01 ft./min. is maintained, the tendency is to utilize the full retention volume. In Fig. 4 the side inlet would be better replaced by, for example, a pipe coming in at the bottom, giving a central feed and better distribution throughout the tank.

On the design of filters, I prefer siphon waste draw-offs. Have the authors any comments on the use of surface wash, using a high-pressure, usually rotating, jet? That is widely used in the U.S.A., but not in the U.K. Have the authors had experience of that system of washing, and, if so, what do they think of it?

With regard to oil removal, the authors have dealt with ordinary methods of flocculation using chemical feed, but electrical de-oiling has also been used effectively. Ferric hydroxide is produced by passing a direct current between iron electrodes. A number of plants have been installed.

In regard to the section on feed-water conditioning, I would emphasize that certain selected tannins have a very high absorptive capacity for oxygen, and can very often replace sodium sulphite for the removal of residual oxygen from mechanically de-aerated water. They have the advantage of forming a corrosion-protective tannate film on iron surfaces.

Finally, the use of activated silica as a seed for coagulation is and has been a very effective method of aiding flocculation. I have seen spectacular results where silica has been used with lime or aluminium sulphate. The authors mention methods of neutralizing bicarbonate to obtain the sol, and they refer to the use of chlorine. I feel that the use of chlorine may have much greater application in future, because it has two advantages in water: it forms hydrochloric acid plus hypochlorous acid, the former being used to neutralize the silicate and the latter producing chlorine for water sterilization and the prevention of algæ growths. It is also possible to have a concentrated solution of the activated silica, which solves the difficulty of having large tanks with long periods of ageing.

Mr. **Lamb**: Although solution feed is ideal, I cannot agree that dry feeders should not be used at all. The conditions for using a dry feeder must be different from those where solution feed is used; *i.e.*, a dry feeder must be kept in a room at a certain temperature so that there is no risk of the dry powders caking. We have supplied many dry feeders for various chemicals in the past few years which are giving complete satisfaction.

Mr. Streatfield suggests that hopper-bottom tanks are more or less obsolete, and that the general practice is to use vertical flow tanks. Figure 4 in the paper certainly shows side inlets, but is diagrammatic; normally the water is brought down a centre tube and dispersed over the bottom, and then rises upwards.

I have had very little experience of the surface wash with a jet and do not know of any cases where it is used in the U.K. We have found that the siphon wash is not only very efficient for cleaning the filter media, but that it also enables economy in wash water to be obtained.

The paper refers to one alternative method of de-oiling, by using kieselguhr filters, which has been tried on a number of occasions, with satisfactory results. This eliminates the use of coagulants, and the plant is considerably smaller than the normal chemical treatment de-oiling plant.

Mr. **Waddington**: I agree that the modern tannins are very effective as deoxidizing agents and have the added

advantage, as Mr. Streatfield points out, of providing a protective film.

Activated silica has been in use for some years, and various applications of it have been made. However, a number of active agents can be used for activation, the choice depending on the water to be treated and the purpose for which it is being used. Thus, for instance, with a lime precipitation softener or a lime-soda softener, using activated silica, sodium-bicarbonate-activated silica would obviously be advantageous, because sodium carbonate is formed from the bicarbonate. In the treatment of river water, the use of a chlorine-activated sol might prove beneficial, since there is a certain recovery of chlorine. Sulphuric acid, the cheapest of all agents, can also be used. Attempts have been made to use aluminium sulphate as an activating agent, and it has been used in the U.S.A. under the name of 'the Graf–Schworm' process, but tests in my laboratory have not proved very successful. Similarly, ammonium sulphate has been used on occasions as a source of ammonia for the activation of silica.

All these agents can be used, but there are two methods of making activated silica: the batch method and the continuous or semi-continuous method. In the batch method, the tankage is enormous for any considerable volume of water to be treated, because the sodium silicate and the activating agent must be brought together so that the strength of the silica in the sol when being aged is 1·5%. As soon as it has been aged (usually for 1½–2 hr.), it is diluted to 0·75–1% of silica, in which condition it is stable for about 24 hr. The weaker the sol, the greater its stability; the activity of the sol depends on the ageing period.

We have seven plants working on the semi-continuous process, in which very high concentrations of sodium silicate and the activating agent are brought together. We usually use 4% or 5% solution and age for only 9–10 min.; it is then immediately diluted and applied to the water. The treatment merely consists of adding one tank of strong sodium silicate to one tank of strong sodium bicarbonate or acid in a small vessel with a retention time of 8–10 min., immediately diluting and adding to the water.

The danger with sodium-silicate-activated silica sols is gelling; if they are not properly aged and diluted, the result is a 900- or 1000-gal. tank full of very soft jelly, which has to be removed.

Mr. **C. D. Poucher** (United Steel Companies, Ltd.): Under the heading "Feed-Water Conditioning" the authors refer to the injection of sodium sulphite for protection against caustic embrittlement in boilers with riveted drums. Should not this apply also to boilers with forged and/or welded drums? There may be a possibility there of embrittlement at tube expansions. Have the authors had any experience of the use of accelerators in connection with sodium sulphite? I believe that cobalt salts are used for this purpose.

Attention must be paid to the selection of personnel for water-treatment plant, because much can depend on them in its operation. They should be told in simple terms exactly what lies behind the job, and then there will be less chance of mistakes and slipshod methods, because the men will understand why they are doing certain things.

Mr. **Waddington**: Embrittlement is likely to take place at points of tube expansion, and therefore preventive treatment and control of concentrations of the various sulphate/carbonate ratios are desirable. We have had some experience in the use of cobalt salts added with sodium sulphite, but mainly on the Continent. Some operators of high-pressure boiler plant (about 900 lb./sq. in.) are still perfectly satisfied to add sodium sulphite by itself. There is also a body of opinion in favour of the use of sodium sulphite for deoxygenation, but at the moment, apart from hydroxylamine, I do not think that there is any other reagent for that purpose.

Personnel should be told what the plant is supposed to do; it is not fair either to the users of the water or to the manufacturers of the plant to put inferior workmen in charge of the water purification plant, as is the practice in many works. A man who has an accident and loses an arm is often put in charge of the water-treatment plant, as a 'soft' job. There may be a softener with a ladder in the plant, and such a man will never go up the ladder to see what is happening at the top of the plant.

Dr. **F. A. Champion** (British Aluminium Co., Ltd.): There appears to be no mention in the paper of micro-mesh screens for filtration; do the authors regard them as adequate, following coagulation and settling, for the provision of a clear water where the problem is simply to avoid any appreciable suspended solids, without worrying too much about the dissolved solids?

Mr. **Waddington**: Micro-mesh screens are being used increasingly, both in municipal waterworks and in industry, but, as with all types of water-treatment plant, there are limitations to their use. Makers of micro-mesh screens would not feel very happy about removing floc produced by coagulation. Where they are successful is in the removal of algæ and diatoms. Many waterworks put them in advance of their slow sand filters to remove the minute diatoms, etc., and by so doing have increased the output and rating of these filters by as much as four, five, or six times. Micro-mesh screens are used in certain industries for trapping fibres, but only pilot tests can prove whether they are going to be successful.

Mr. **Lamb** then showed a number of slides of various types of water-treatment plant.

Mr. **A. Stark** (Steel Peech and Tozer): Water treatment is not a prerogative of the chemist. There are three factors from the engineer's point of view: the cost of treatment, the scale which has to be dealt with internally in pipes, etc., and corrosion. The problem of water treatment must be tackled seriously as a commercial proposition.

From the corrosion standpoint, do the authors recommend a lime-soda softener treatment for dealing with boiler-feed water or a zeolite–hydrogen-ion plant? Have they any preference for the type of treatment for Lancashire boilers, waste-heat boilers, and water-tube boilers?

Mr. T. H. Turner mentioned the type of water treatment used on locomotives for some years. How are the sludge, scale, and general concentrations eliminated? Is that done by ordinary blowdown or by some form of continuous blowdown?

We have been dealing mainly with the chemical treatment of water. For the treatment of boiler feed water against corrosion we have tried sodium sulphite, but we think that a better treatment for dealing with corrosion in boilers due to free oxygen in the feed-water is a mechanical de-aerator. The initial cost of a de-aerator together with operational costs is (over a period) less than that of treatment by adding sodium sulphite in the feed-water entering the boiler.

Water for boiler feed should be treated externally and should be as nearly as possible perfect in condition before entering the boiler. Everything that might influence sludge and scale in the boiler should be removed in pre-treatment and not dealt with in the boiler.

The question of dry feeders *vs.* wet feeders is largely a question of cost. Dry feeders are useless on top of a plant unless consideration is given to keeping the

chemicals dry. We have dry feeders which are working very well indeed, but it was necessary to provide a proper building, to heat it, and to have proper access for chemicals and keep them dry. We are perfectly satisfied with our dry feeders, but if the chemicals were allowed to become damp, they would be useless.

Engineers should give more time to water treatment, because it is becoming increasingly important. In a large steelworks four types of water are needed: roughly filtered water, properly filtered water, softened water, and town's water. Tests reveal how much money is lost in treating water which is then allowed to run to waste after use. We have a river running through our works, and people often say "We are short of water, and here are millions of gallons in the river." Very often a mistake can be made by treating water and using it as all-purpose water when ordinary raw river water, roughly filtered, would suffice for the requirements.

I suggest that water treatment in general should be part of the training of all junior engineers, and also that more collaboration should take place between works chemists and maintenance engineers.

Mr. **Waddington**: More friendly co-operation between engineers and chemists would often make a water-treatment plant work very much better than it does in many works.

No two waters are alike, and each must be considered individually. For a water high in temporary hardness or alkaline hardness, lime softening is desirable, because lime is the cheapest method of removing and precipitating the bicarbonates of calcium and magnesium; the removal of temporary hardness from that water will thus reduce the soluble solids. For permanent hardness soda is used. If there is only a small amount of permanent hardness and a large temporary hardness, the lime-soda process is ideal. It produces, however, a water which has a fairly high alkalinity, and if there is a large amount of magnesia hardness present a high excess alkalinity will be needed (in the absence of heat) to precipitate that magnesia as completely as is desirable.

On the other hand, with a water with mainly permanent hardness, base exchange is always preferable, because the cost of the salt required for regeneration is comparable to the cost of the soda that would have to be used to remove that permanent hardness. With a water such as I described for the lime-soda softening, passing it through the normal base-exchange softener will give a very high sodium bicarbonate content in the finished water; the soluble solids will not be reduced, and consequently the water will be virtually corrosive. In some large electric power stations the water is lime-softened only; it is then acidified and finally passed over to a base-exchange softener to remove the permanent hardness. That is for water frequently going to evaporators.

So far as the different types of boiler are concerned, with a water-tube or waste-heat boiler the character of the water is more important than for low-pressure Lancashire boilers. With a low-pressure boiler internal conditioning rather than external softening would on occasion be preferable. Up to a point I agree that external treatment is desirable, but certain reactions take place in the boiler, and it is to correct the products of these that sodium sulphite or one of the phosphates or tannins is added for final conditioning. Most modern power stations have internal conditioning with phosphate and sulphite.

I am not sure what advantage town's water would have over properly filtered water or softened water, but I agree that for many purposes only roughing filters are required. On the other hand, where these various types of water are introduced, the expenditure on mains, cross-connections, etc., will often outweigh any advantages or savings which may be obtained by preparing water of two or three different standards. There are only about three places in the U.K. which have an industrial supply as distinct from their ordinary drinking water.

Mr. **T. H. Turner**: The question of steam locomotives is probably of interest to many steelworks. The blow-down should be from the bottom and not from the top. Intermittent blowdown will remove more of the sludge. Engineers used to be frightened of a bottom blowdown, for fear the blowdown valves would stick open, but there are types of blowdown valve which do not give trouble. The French Railways and the Southern Region of British Railways use this system. The former London Midland and Scottish Railway introduced continuous blowdown, from near the top. It was thought that if the blowdown take-off were about 2 in. above the top of the firebox they would be safe if a blowdown valve stuck open. That system has, however, cost a great deal of money, because the blowdown continuously on the track results in so many rail breakages that the civil engineer loses more than the mechanical engineer has gained.

Another question was whether to use external or internal treatment, pre-treatment, or conditioning. If London water is considered to be hard and Birmingham, Liverpool, and Glasgow waters to be soft, there must be some intermediate water, such as that at Derby, which is on the borderline from the point of view of whether or not to treat it externally. External plant is needed for London water, but not for Birmingham water. Above about 100 p.p.m. (or, say, 7° Clarke) an external treatment is needed; below that, internal treatment only will generally suffice. These alternatives are not mutually exclusive; what is needed for boiler treatment with a bad water is external treatment first, followed by internal treatment. From time to time the softener may go out of action or the pipes may be misconnected and raw water may be mixed with the softened water. That will lead to failure in the end, but there will be no failure if the water in the boiler is tested daily and chemical treatments are altered accordingly.

Mr. **G. W. Cook** (Appleby-Frodingham Steel Co.): Has Mr. Waddington any knowledge of the types of trouble experienced as a result of synthetic detergents when lime-softening water which contains them?

Mr. Waddington said that where a starch-based coagulant will give good results, activated silica should at least produce equal results, if not better. I have in mind one case where we definitely get good results from a starch-based coagulant, but so far the efforts with activated silica, in spite of the variations which have been made with regard to the ageing period, the time of addition relative to that of other chemicals, the point of application, etc., have proved ineffective.

Have the authors any knowledge of the application of the colorimetric determination of hardness, and has that been applied, or has an attempt been made to apply it, to the automatic control of, say, the lime-soda softening process?

Mr. **Waddington**: The effect of detergents on water which is to be lime-soda softened will be to cause excessive foaming, with occasional interference with the effectiveness of softening, and the foam will be found to persist even after that softened water has been filtered. That is the main difficulty when using a water which contains excessive amounts of detergents. Much work is being done at the moment on the estimation of detergents, which is by no means simple, since it is almost impossible to recover the whole of the detergent in a particular water and so get an accurate estimate. It is early to make a definite statement, because their use is relatively new, but it is spreading so much that they are beginning to have an effect on treatment plant generally.

So far, no easy way of removing them or of correcting their detrimental effects on treatment plant has been found. The limiting concentration is apparently 3–5 p.p.m.; below that figure the difficulties experienced are not very serious.

Each water must be treated individually, and so I am not surprised that for a particular water Mr. Cook has found that a starch-based coagulant is more effective than activated silica, possibly in conjunction with lime.

There have been a number of laboratory instruments using the new E.D.T.A. hardness test, the colorimetric hardness test, photo-electrically, for hardness determinations, but I do not know of one which is on the market for application for control purposes. This method is, comparatively speaking, still in its infancy. It may be some time before it has been explored sufficiently to justify its use for control purposes, but as a hardness test it is excellent in every way.

PROCEEDINGS OF THE AFTERNOON SESSION: 2.0 P.M. to 4.0 P.M.

Discussion on the Paper—

MODERN INDUSTRIAL BOILER PLANT*

Mr. **W. P. C. Ungoed** (Steel Company of Wales, Ltd.), in presenting the paper, expanded some of the points raised in the paper, and showed a number of slides to illustrate future developments in industrial boiler plant.

Mr. **R. McDonald** (Colvilles, Ltd.): Mr. Ungoed has given a broad survey of the problems associated with modern installations, and his paper can be accepted as a valuable contribution to the iron and steel industry.

When determining working pressure, the essentials of any projected or new installations are as stated by the author, namely, high availability, minimum operational and maintenance costs, and high overall efficiency. The criterion to meet these requirements is the determination of working pressure; this should be regarded from an industrial aspect, as distinct from power-station practice, where the function is the generation of power. In power-station practice scientific, operational, and maintenance staffs are adequately provided, and, since no process operation is involved, the working pressure is usually selected in relation to the final steam temperature, which is, of course, dependent on the heat-resisting materials available.

The selection of working pressure for industrial practice, however, will vary according to the relative demands of power and process steam. There are an enormous number of individual plants for steam generation for process work throughout the country, from 3000 lb./hr. upwards, but it is difficult to state at what evaporation power generation should be incorporated.

If it is decided to embark on power generation, either the back-pressure engine, the back-pressure turbine, or the pass-out turbine will be adopted. The relative demands of power and process steam determine the range for working pressure. Where back-pressure units can be adopted, only a proportion of the required amount of process steam can be utilized for power, the remainder passing direct from the boiler to process. No advantage can be gained by increasing the working pressure, since this would decrease the requirements of the back-pressure unit, and there would be no resultant saving, because the difference would have to be transferred to the direct process.

Where the power and process demands are dealt with by the pass-out turbine, the working pressure should be as high as practicable so as to reduce the condenser load to a minimum. This working pressure would in many cases approach power-station standards of 900 lb./sq. in. and 900° F. Such conditions for industrial practice would therefore demand the same standard of staff as do power stations. The working pressure for such conditions seems to be best determined by the practical and technical experience of the engineer responsible.

Although the introduction of welded joints in superheaters may be accepted, this type of joint in economizers must be viewed with a certain amount of reticence, since the feed water must be maintained at the highest possible standard. This can be attained in power-station practice, where only a small amount of distilled water is required for make-up, but it is more difficult in industrial practice with varying amounts of returns and make-up. Although the specialists can advise on water treatment, there is still a gulf between theory and practical application. In fact, water treatment should be regarded on the same basis as CO_2, since both are of major importance in the operation of boiler plant; yet there are no reliable instruments to indicate values which engineers can accept with confidence. The requirements of the insurance companies, that 25% of economizer bolted joints be dismantled for examination at the annual inspection, provides a periodic check on the standard of water conditioning. Although this involves a certain amount of additional maintenance in comparison with the welded joint, a few tube failures caused by faulty water treatment are sufficient for insurance companies to demand in all such plants that a certain number of bends be cut off each year for examination.

To obtain maximum efficiency with high pressures and superheat, stage bleeding is introduced in the turbine, resulting in elevated feed temperatures of about 350° F. The boiler unit would then have to incorporate an air heater, so that for stoker-fired units, in addition to deposits in the air heater, the range for bonded deposits in the economizer has been reached. With the addition of an air heater, water-cooled furnaces are essential, and the complication of power-station standards has been attained. Some very large steelworks operate up to 600 lb./sq. in., but practical experience suggests that, where high pressures can be adopted, an economic value for industrial practice is about 400–450 lb./sq. in.

High pressure, with correspondingly high final steam temperatures, does not necessarily mean higher-efficiency steam generators, since the efficiency of these

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is determined by stack loss. For example, on a 160-hr. test under normal working conditions of an 18-year-old brick-set 5-drum boiler with economizer, operating at 200 lb./sq. in., an efficiency of 83% was obtained, the stack temperature being 290° F. and the CO_2 11%. Industrial establishments with high steam outputs could expect substantial economies from existing plants by employing expert combustion engineers possessing not only the necessary technical qualifications but also two or three years' practical experience on the firing platform.

In regard to final gas temperature, the author gives a safety margin of 40° F. over the dewpoint, elevated by the sulphur trioxide present, but I would suggest that the metal temperature is also of primary importance. With air heaters, is it not normal practice to recirculate a percentage of heated air to maintain a metal temperature well above normal dewpoint ?

On the subject of soot blowing, Table II shows a stoppage of 4¾ days on boiler 1 for economizer gas-side cleaning. Might part of this fouling be caused by the whole system becoming pressurized during soot-blowing operations, owing to a time-lag in induced-draught fan operation? Has the author any experience of increasing the fan speed manually before soot blowing?

From experience in industrial practice, where the make-up is 100%, I think that mechanical de-aeration should be adopted for pressures very much below 250 lb./sq. in. With certain types of water-softening units, severe corrosion can be expected in feed lines, and ' holing ' due to corrosion can be disastrous in a boiler range fed through a common feed line. The cost of chemicals to reduce the oxygen content from about 3 c.c./l. to 0·03 c.c./l. and under would be prohibitive, and on this basis, coupled with continuous operational availability, the capital cost of de-aerating unit would be justified.

In the steel industry an important contribution to power requirements can be effected by waste-heat steam generation. Where waste-gas temperatures at the boiler inlet are 1200–1300° F., a final steam temperature of about 730° F. can be obtained at a corresponding pressure of 170 lb./sq. in.

Mr. **Ungoed:** The modern plant described is of advanced design and requires a high standard of technical ability of both management and men. To make it successful, many technical training schemes were started, and, as a result of the offer of suitable incentives, the response on the part of the men has been more than was hoped for. The standard of education aimed at has been the preliminary, intermediate, and advanced certificates of the City and Guilds Institute on boiler-house practice; on our next extension, possession of the appropriate certificate will be a condition of employment.

If economizer welded bends are to be used, the feed-water quality must be equivalent to condensate. The saving in operational failures by the adoption of welded joints will mainly apply to boilers, which are on either intermittent or widely fluctuating loads. There is, in addition, a small saving in feed water in comparison with the clamped economizer joint, which requires a constant bleed-through of feed water, to keep the joints at normal working temperatures during starting or shutting down.

The all-welded superheater is far more common at the higher temperatures, as there have been repeated failures of the ball-and-socket joint, particularly at operating temperatures of 800° F. and above.

The overall efficiency of 83% quoted for a brick-set 5-drum boiler is very creditable, particularly for such an old installation. A modern plant should have a test efficiency of not less than 85%, but in addition, by the adoption of higher working pressures, gains by the increased energy potential of the steam generated are available.

Air preheaters are a difficulty, particularly in regard to bonded deposits. Mr. McDonald is perfectly correct in his statement that the operating metal temperature determines the rate of fouling. In the case of rotary preheaters, the operating temperature of the metal undergoes a continuous cycle, and is the mean of the maximum and the minimum of both air and flue gas. To avoid corrosion, recirculation of either flue gas or air, or both, is widespread practice.

The down time of the economizer mentioned in the text of the script was entirely devoted to cleaning and the inspection of economizer bends. The boilers in question are fired by blast-furnace gas, oil, or coke-oven gas, and are therefore not fitted with soot blowers.

In the case of the pulverized-fuel boilers, it is customary to increase the induced fan draught to avoid blowing grit out at boiler access doors, etc. At the same time, care must be exercised not to increase the draught to the point where instability of the flame may occur.

On stoker-fired boilers, soot blowing is more of a problem, and its usefulness for dealing with combustion-chamber deposits is very doubtful. Water lancing is quite effective, and does no damage to tubes or headers in the process.

Mr. **L. A. Fullagar** (McLellan and Partners): In an integrated steelworks the ideal condition is that all the purchased coal goes to the coke ovens, and all requirements for power, process steam, and space heating are met from surplus fuels unsuitable for export. Boiler plant will have to consume blast-furnace gas and possibly coke-oven gas and breeze, and utilize waste heat from the melting shop, slab reheating, and other furnaces. In designing boiler installations for the Steel Company of Wales at Margam it was found more economical in capital and running costs to have no solid fuel on the main boilers, thus saving considerable space and outlay on plant which would have had a poor load factor. The solids (mainly poor quality breeze and other surplus products) are dealt with in less expensive plant linked with the main boilers and devoted to process steam and space heating. Thus, each boiler installation is designed for optimum steam conditions and closely related to the fuel available, since boilers are only one of the fuel-using and heat-producing installations in steelworks.

Using surplus fuel, a steelworks can generate electricity more cheaply than the Electricity Authority can afford to sell it, but it is less easy to generate profitably from purchased fuel, and for the occasional emergency the convenience of oil firing justifies its use.

The reference on p. 287 to the selection of steam conditions should perhaps make it clear that, as there is probably a considerable range of boiler pressure over which process steam can be obtained from pass-out turbines, the choice may depend on relating the capital and operating costs for plant working under various steam conditions to the values of the electrical output obtained.

For success, reheating requires large units and steady loads. For secondary steam plant, forced-circulation boilers can use the same grate and fuel equipment to supply steam alone in summer or steam plus space-heating hot water in winter, thus maintaining an efficient level of output.

There seems to be little advantage in a gas temperature of 1400° F. entering the economizer. The relatively small flow of water through an economizer section makes some recirculation desirable, and the economizer becomes part of the boiler. The higher gas exit temperature also transfers heat from the economizer to the air heater, and it seems preferable to leave the economizer to its duty as a feed-water heater.

Boilers are now being placed in the open, thus saving a considerable tonnage of steel, but great care in design is needed if operation is to be satisfactory in the British climate. Pressure combustion may possibly be adopted to a greater extent. This will allow a welcome reduction in the size of gas mains; leaving out an induced-draught fan saves space. The compression of blast-furnace and coke-oven gas is no longer a difficulty; it is common practice for other purposes. With blast-furnace gas, complete gas-tightness is essential, and even with welded casings the present technique may not be adequate.

In a steelworks the demand for steam for works use is considerable, and much of it is often supplied at a higher pressure than necessary, involving loss in generation. Transmission over long distances and mains layout throughout the works should be designed for minimum losses. By the use of suitable pass-out and back-pressure turbines and by an economic choice of boiler-steam conditions the highest return on capital outlay is possible.

In considering the combustion-chamber volume, in addition to the cubic content, the shape is important in relation to the fuel. Users other than the steel industry have rarely such large demands or such convenient availability of surplus fuels and waste gases. Modern techniques must be applied not only to the main boiler plant but also to the more efficient use of waste heat wherever it is found.

Mr. **Ungoed:** The costing of steam, and the problems of whether the electricity produced can be competitive with the British Electricity Authority, depends on the accountancy system of the works. In our company, blast-furnace gas is paid for at the same cost per B.Th.U. as bought fuel. It is not treated as a waste gas and regarded as valueless.

The main query raised by Mr. Fullagar is the high economizer inlet-gas temperature quoted as being acceptable in modern designs. The early designs, as illustrated in the slides, were of a tri-drum boiler with a fairly large bank of convection tubes. It has now been accepted by boiler designers that for a close compact boiler, the large convection bank is not economical. Consequently, we have the high-duty steaming economizer, with an entering gas temperature of 1400° F., raising thereby up to 10% of the total steam. A final air preheater is essential.

The shape of the combustion chamber is extremely important for gas or oil firing, if the flame path is to be of the free-jet turbulent-flow type. Any direct impingement on the combustion-chamber wall slows the flame down to such an extent that it prevents the creation of the turbulence, which is essential for the high rate of heat transfer.

Mr. **T. H. Turner** (British Railways): Although the discussion so far has dealt with the more modern types of boiler, it is clear from the paper that there are many old boilers which the industry will have to treat; in recent years a quarter of our coal has been burnt in Lancashire boilers. When the British Standard code of practice for the treatment of water for land boilers was drawn up, a limit was fixed at 600 lb./sq. in., on the assumption that anything above that was experimental. The B.E.A. and some others work at above that figure, but they usually have chemists whose task will be to find out what happens. However, the code of practice covers most of the boilers referred to in this paper, mainly below 250 lb./sq. in., with considerable heat storage. That is a feature which is very helpful, for example, in a locomotive boiler, compared with the Diesel engine; this storage of heat in the furnace and in the mass of water and steam in the boiler is available to meet emergencies. That must be of value in a steelworks also, and in the newer boiler designs one of the troubles which will be encountered is that the thermal storage for emergencies will be less.

The author spoke of the rate of scale formation; he should have added that there ought never to be any. Ten years ago I went inside an aircraft carrier's boiler after many months of service, with its water correctly chemically treated; it was so perfectly clean that we had to convince ourselves that it had not just been cleaned. It is possible in operating a water-tube boiler to have absolutely no scale visible, although it is more difficult to say that there was no thin silica scale. Boiler scale should not now be permitted on the water side of the boiler.

The emphasis is now on the fire side of the boiler. So far as marine boilers are concerned, the problem of internal corrosion has been almost solved, but not the problem of stopping the deposits on the outside; boiler availability is now not a question of taking the boiler off to descale the inside, but of doing so to descale the outside. There are two possibilities: either a wet lancing arrangement must be used to wash off as much as possible, or (at the risk of incurring the displeasure of the Atmospheric Pollution Committee) it must be blown out.

In one of our works there are two men constantly employed in cleaning roofs because of the Company's cupolas. The management of a well-known steelworks decided that whenever a new scheme requiring capital expenditure was drawn up, a memorandum should be attached to it dealing with smoke abatement or grit protection. That company is to be congratulated on its foresight, and this example should be followed, because it is the works personnel who are first troubled by this grit. Steelworks will help themselves and others if they pay attention to the question of atmospheric pollution. These new types of boiler will help, but the fly ash from pulverized coal is a great nuisance. If pulverized fuel is used a cyclone or grit arrester should be installed.

Intergranular cracking may occur when the boiler-water treatments mentioned on the last page of the paper are used. In B.S.1170 the sulphate ratio is recommended. When the last specification of the series was drawn up, Dr. W. H. J. Vernon, Chairman of the Corrosion Group of the Society of Chemical Industry, organized a symposium on the subject. As a result of this symposium the recommendations in B.S.1170 and the new specification for land boilers were slightly altered.

Mr. **Ungoed:** Feed-water treatment is the basis of all good boilerhouse practice. We have been particularly free from trouble; corrosion is non-existent and scale-forming completely absent. We have taken careful precautions against the possibility of intercrystalline cracking, by maintaining a fairly closely controlled sulphate/phosphate ratio.

The problem of corrosion has come up in connection with oil-firing. There has been some failure of some of the hot metal parts of superheater supports as a result of vanadium pentoxide attack. A number of marine designs use water-cooled separators to hang the superheaters on, as an integral part of the boiler circuit.

Commander **J. I. T. Green** (B.I.S.R.A.): Although the Plant Engineering Division of B.I.S.R.A. has not dealt with boilers, I have been interested in naval boilers for some years and would like to draw some comparisons between them and industrial boilers. A great variety of boilers have been tried at sea, including some with forced circulation. During the last 25 years the progress

in heat-transfer technique, oil firing, and water treatment have resulted in a steady increase in reliability and availability and a greatly increased heat release per unit volume. In the author's Table I, showing the rate of steam production, the highest group is " 40,000 lb./hr. of steam and over." A destroyer's boiler, however, produces 200,000 lb./hr., and two or three such boilers can be fitted into the ship; an industrial boiler developing equal power would almost sink the ship if placed on board.

The main aim in naval boilers is thus high power in a small space, and advanced designs are very necessary. It is not clear to me why industrial plants should require such design treatment.

The figures of heat-transfer coefficient differ very widely between Figs. 2 and 3. Those on the gas side in Fig. 2 are one-tenth of the figures of heat transfer shown in Fig. 3. It is therefore quite useless to try to improve the figures shown in Fig. 3, because the controlling influence in heat transfer between gas and water is the resistance on the gas side. The author's remarks on p. 284 about the beneficial effect of forced circulation are therefore not clear.

It is mentioned in the paper that economizers contribute 10% of the evaporation, so that they do not really justify the name. If regenerative feed heating is used to bring the feed water up to saturation temperature there is nothing left for a true economizer to do. A choice has to be made between minimum boiler uptake loss and maximum thermodynamic cycle efficiency, and it would be interesting to know how this is decided.

Mr. **Ungoed:** Not only do the boiler plants in destroyers have to be designed for minimum space; they have also to be designed for maximum efficiency, because they have to carry their fuel with them.

The question of the exact choice of economizer area, economizer temperature, bled steam, feed-water heating, etc., has to be worked out in each particular instance. It is true that some of the advanced designs have been adapted for marine boilers, but the only advantage of low-pressure forced-circulation boilers seems to be that the boiler size is considerably reduced by the increased rate of heat transfer obtained by the forced circulation.

Mr. **C. E. Sayer** (McLellan and Partners): In the Sankey diagram (Fig. 1) I am not quite clear about the chopped-off corner at the bottom of the diagram representing 'Imported electricity, 4·98.' I think the author has said the diagram is based on the Margam plant, and if it is an integrated diagram for the whole of the Port Talbot–Margam–Abbey Works, I should have thought the imported electricity would represent a much larger item in the make-up. If, however, it represents only the imported electricity (or its heat equivalent) to the power plant, why does it appear again with the generation?

In Fig. 6 the 'efficiency' ratio on the vertical ordinate is apparently just the thermodynamic efficiency of the turbine plotted against steam quantity per unit, at various exhaust pressures, and so merely shows the gain in that efficiency from increasing the size of units. When choosing the size of units, one naturally bears in mind that the larger one can make them the higher will be their thermodynamic efficiency, but in my experience it is very rare to be able to make that consideration the major factor in deciding the unit size, which is usually based on other considerations. In the original planning of the Margam plant we fixed the size of the main alternators at 8 MW., based entirely on what was estimated to be needed to ensure complete absorption and efficient use of all the steam produced from the blast-furnace gas expected to be available.

In dealing with the choice of boiler pressure for new plant, a previous speaker referred to 400–450 lb./sq. in. as the optimum boiler pressure for industrial installations. It seems to me unsound to lay down a hard and fast figure in this way, because the question must depend, to a considerable extent, on the scale of the plant being considered. Referring again to the original planning of Margam, as the scheme grew larger and larger the intended boiler pressure was raised, as it seemed right to relate the pressure to the intended scale of operation. Ultimately, the figure of 600 lb./sq. in. gauge was arrived at for the scheme as it finally stood, since it was felt that this pressure, at any rate at that date, was as high as was desirable for an industrial plant of this type.

Mr. **Ungoed:** The small chopped-off part of the Sankey diagram referred to is the imported electricity converted back to B.Th.U. The whole diagram is based on B.Th.U. equivalents for the particular period covered.

With reference to the curves illustrating the gains for back-pressure generation, Fig. 6 shows the efficiency ratio as the vertical ordinate, and is intended to illustrate the gain in efficiency through increasing the size of the units. The choice of optimum steam pressure for an industrial installation depends entirely on the size of the proposed plant, and whether the increase in pressure can be used efficiently in the turbine plant. Up to certain small sizes of back-pressure turbine, there is no great economy to be gained by raising the steam pressure, as the blade-tip leakage steam becomes too large a proportion of the total, owing to the very short blade lengths.

Mr. **C. D. Poucher** (United Steel Companies, Ltd.): In the past insufficient attention has been paid to the question of steam purity, especially in connection with low-pressure and medium-pressure boilers. Boiler manufacturers should pay more attention to this point, including the provision of suitable steam sampling points. Furthermore, desuperheating by feed water ought to be abolished. It seems illogical to aim at pure steam and then spray feed water in it.

Another point in connection with steam purity is the effect of the recently introduced anti-foams on boiler design and boiler-water conditions. What are the author's views on that point?

The use of phosphates alone in boilers introduces a possibility of the deposit baking on the hotter part of the tubes, leading to overheating of the tubes. What is the author's opinion on this subject?

Mr. **Ungoed :** Steam purity is very important for ensuring the maximum availability of turbine plant. For small industrial turbines, steam should not contain more than 6 p.p.m. of impurities. Above that concentration, there is an ever-increasing danger of fouling the turbine blades. The best modern practice today is about 0·5 p.p.m. on large central power-station boilers.

On a projected extension, we are installing a continuous steam sampling, from which the condensed gases are removed and the dissolved solids in the collecting sample are estimated electrically. The object of degasifying the steam sample is to remove the ammonia, which remains in a closed boiler-turbine cycle.

I agree with Mr. Poucher's remarks about desuperheating by feed-water injection. I fail to see any merit in this system, which has several disadvantages. It is preferable to carry out temperature control entirely on the gas side of the boiler, by either by-pass dampers or flue-gas recirculation, or by a combination of both.

The use of anti-foaming devices in the boiler water usually only applies on low-pressure boiler installations, where high concentrations of reagents, which add to the surface tension of the boiler water, are used. Our

main reagents for boiler-water treatment are sodium sulphite for final oxygen absorption and tannin phosphate to assist in sludge mobility.

Mr. **B. A. Sard** (The Permutit Company, Ltd.): Nowadays there is no excuse whatever for scale formation in boiler tubes. Where it does occur, it is not because the water-treatment plant is not capable of fulfilling its function, but because there has not been adequate control. In one works samples from the water-treatment plant and from the boiler were examined at least once a shift by a competent laboratory, and the results were passed on to the engineering department by the chemist in charge. Unfortunately, he made no comments on those results, because he claimed that it was not his responsibility. It was therefore made his responsibility, and that part of the plant now works very much better.

I disagree with the author's comment that, if the economizer bends are welded, it is necessary to have distilled-quality water. It is possible to make a water non-scale-forming and non-corrosive without making it the equivalent of distilled water.

In regard to de-aeration, there are far more old boilers which want tidying up than there are new boilers. The author mentions on p. 290 that the vacuum-type de-aerator is giving way to the pressure type. My experience is that the pressure type, although cheaper than the vacuum type and just as efficient, suffers from the disadvantage that the water temperature as the water leaves the de-aerator is so high that the average feed-water system cannot handle it. Has the author any suggestions for overcoming that difficulty with existing boilers, especially those fitted with economizers?

Finally, mention has been made of the undesirability of using feed water for the desuperheater. One 600-lb./sq. in. boiler plant has just had a de-ionizing plant installed to produce very high-quality water purely for feeding a spray-type desuperheater.

Mr. **Ungoed :** The principal difference between the vacuum and pressure de-aerators is the considerable simplification of the total plant required for the pressure type. The vacuum de-aerator for a 600-lb./sq. in. system requires low-pressure and high-pressure feed-water heaters. The pressure type, on the other hand, does the whole job in one vessel, which, with the reduction in space requirements and the number of pumps for its operation, makes it very desirable.

Water of distilled quality is essential for all welded economizers, particularly those of the high-duty steaming type. The difference is that, in the high-duty economizer, steam is raised from feed water as distinct from boiler water, and there is not the same margin of safety against corrosion. To surmount this difficulty, in some installations it is necessary to recirculate a proportion of the boiler water back to the economizer inlet, so as to give the economizer water a sufficient reserve of *p*H to inhibit corrosion. To provide this protection by directly increasing the chemicals added to the feed water merely adds to the total water blown down from the plant.

Dr. **F. Wormwell** (Chemical Research Laboratory): I have been expecting the author to say what percentage of the time the boilers were out of commission was due to corrosion troubles; so far, the corrosion appears to have been negligible. It is to be hoped that that state of affairs will continue; it must have been due to constant vigilance. The control of corrosion or scale formation is a matter of carrying out thoroughly the advice of experts.

A fairly short period of running on an oxygen content of 0·5 ml./l. or more has proved in the past to start very severe localized corrosion in boilers working in the 1000-lb./sq. in. pressure range. Can the author comment on that?

I believe the opinion has been expressed that the most difficult corrosion problems seem to arise at heat-transfer rates above 100,000 B.Th.U./sq. ft./hr. I understand that these are reached in naval boilers, but I presume that they are not so often reached in land boilers.

Mr. **Ungoed :** At oxygen concentrations of 5 ml./l. and over and at high steam pressure, the rate of corrosion can be so rapid that boiler or economizer tubes can fail in a matter of months. So far as down time for corrosion problems are concerned, both the low-pressure and the high-pressure boilers at the Margam and Abbey works are merely inspected annually, and there has been no internal cleaning in the last three years. The rate of heat transfer which Dr. Wormwell quotes is tremendously high, and might only be found in very highly rated marine boilers.

Mr. **A. S. Peacock** (Babcock and Wilcox Ltd.): On the ordinary B.E.A. Stations, steam-temperature control is not difficult, since dampers and gas recirculation can be included, but in a steelworks the problem is more complicated because up to four fuels may be used, and even on a base load the final steam temperature will vary by 40–60 F. deg. solely as a result of the changing range of fuels. This variation should encourage the use of external controls in the steam range, but they should be kept to a minimum by the use of automatic control on the boiler (particularly air/fuel ratio equipment).

The problem of smaller boilers and high outputs cannot be solved merely by accepting high ratings and small-diameter tubes. This is possible on marine boilers with the fuel and water conditions which often apply at sea. If a high-rated small-tube boiler were put into commission in industry, particularly with solid-fuel firing, the resultant availability would be only a few hundred hours before the whole plant became choked up. The plant submitted to the user must be adjusted to suit the conditions which apply; an attempt should be made to introduce the smallest tubes and the highest mass gas flow consistent with 7000–8000 hr. continuous steaming without manual cleaning.

The author is fortunate in not having to use solid fuel on his boiler plant, but this raises the question of whether steelworks, large industrial users, and the Electricity Authorities should be integrated from a national fuel standpoint. I agree that boilers should be as large as possible consistent with the total demand, and that with good availability standby plant could be almost neglected. I also agree that feed-water questions need not affect availability, which is primarily a fuel problem.

With a boiler of 100,000–300,000 lb./hr. evaporation and considerable electricity generation in the cycle, it is necessary to consider, in the interests of national fuel resources, whether a slight increase in size together with the generation of surplus electricity at times might lead the B.E.A. to import the surplus instead of being called upon to supply the peaks. Continental developments encourage fuel users to generate power beyond their internal needs and without detriment to their process steam requirements. In the steel industry the utilization of higher pressures and temperatures, plus possibly a slight increase in boiler size and perhaps the installation of additional combustion appliances on the same boiler, would lead to higher overall efficiencies and corresponding saving of coal. It is recognized that the boiler is the last user of blast-furnace and coke-oven gas, and that supplies vary and

sometimes disappear altogether, although the steam and power demand may remain almost unchanged. With additional combustion equipment (possibly pulverizing mills) it would be possible to compensate for the loss of gas and remain self-sufficient. At other times—probably most of the year—the generation of power would exceed the steelworks requirements and the surplus should be purchased by the B.E.A.

The conservation of our national coal resources should encourage increased unification among users, to obtain the highest yield in power or steam per B.Th.U. of fuel.

Mr. **Ungoed :** The introduction of high-velocity small-bore boiler tubes with high gas velocities must be accompanied by corresponding improvements on the combustion side of the boiler. I agree that the availability aimed at could give not less than 8000 hr. non-stop service.

The suggestion of integrating industrial electrical generation with the British Electricity Authority deserves very wide publicity, as it can have the very desirable results of reducing industrial generation standby capacity to the absolute minimum. It would also be in the interest of national fuel economy if greater consideration was given to the sale of low-pressure steam to suitable industrial consumers from the central power stations.

In the French steel industry the practice is to pipe all the available blast-furnace gas to the central power station generating electricity from large high temperature and pressure boiler plant. This scheme seems to have the merits of more efficient generation, but the disadvantages of gas-booster and electrical-transmission losses make the saving very problematical. In addition, the absence of steam at the individual works makes it necessary to use constant-speed A.C. motors on the large h.p. drives. On such items as blast-furnace blowers this leads to power regulation and corresponding losses through blowing off to atmosphere.

The authorities controlling the fuel-consuming side of French industry have greater powers of compulsion. Plants are periodically inspected and, if they are not up to the average efficiency, recommendations are made, designed to achieve this standard. If these recommendations are not put into effect, or the improved efficiency is not achieved, the French "Ministry of Fuel and Power" have the necessary powers to close that plant down.

Mr. **W. Ernest** (United Steel Companies, Ltd.): The author has dealt with the power-station-type central boilerhouse, largely applicable to integrated works. It has obviously been impossible to deal in any detail with waste-heat boilers, but this source of steam production is important and is not always fully utilized.

Relating the subject to cold-metal shops, it can be shown that all the steam and the bulk of the electric-power demand can be satisfied from waste-heat steam. That this is not done is partly due to waste-heat-boiler design not having advanced substantially since their introduction about 30 years ago. The author's company is the only one in the industry to depart from smoke-tube boilers, and its experiences may give the lead for future developments.

The particular difficulty in waste-heat-boiler operation is the fouling of tube surfaces, especially in the superheater, resulting in high labour cost and low availability. Waste-heat-steam costs are often of the order of 1*s.* 6*d.*–2*s.* per 1000 lb., and the low pressures attained in shell-type boilers, together with difficulties in maintaining superheat throughout a furnace campaign, do not make the generation of electric power from the steam an attractive proposition.

Because of the small unit size inherent in tying a separate boiler to each furnace, feed-water control is difficult and there is a lower limit to the size of furnace from which steam recovery can be justified. One solution seems to lie with the forced-circulation boiler, because it can be adapted readily to restricted locations, and a central drum can be used to collect waste-heat steam from a large number of small sources in a shop.

Mr. **Ungoed**: I agree that there are several sources of waste heat in the steel industry, where waste-heat boilers have not yet been installed, but the economics of waste-heat boiler installation and operation is an extremely extensive subject. My company's policy is to recover as much waste heat in the form of steam at the highest pressure consistent with the temperature of the waste gases. Final economizers will be added to the existing waste-heat boilers and to all future extensions.

CORRESPONDENCE

Mr. **D. H. Mustoe** (Steel Company of Wales Ltd.) wrote: An examination of Table I shows that the efficiency of steam generation seems to have been a minor consideration so far as most industrial organizations in the U.K. are concerned. Even the more progressive industrial organizations are too conservative in their choice of working pressures, temperatures, and types of boiler plant. Anything above 650 lb. pressure and 770° F. superheat is apparently disliked, and unorthodox types of boiler very rarely appear to be considered, even though they may occupy a much smaller space, may be much more flexible from the operational standpoint, and, in some cases, may have a guaranteed efficiency of 89–91%.

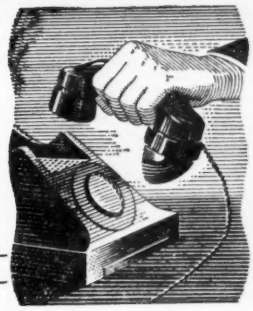
Purely forced-circulated pulverized-fuel-fired boilers steaming at 1500 lb. pressure were installed in one industrial power station in the U.K. in 1938. Efficiency runs of 88·5% and 90·0% were obtained, and the availability has proved to be at least as good as a normal boiler. The flexibility of operation is far better, 1 hr. 20 min. being the time required to bring a boiler up from dead cold to full steaming capacity.

Where it is necessary to build new plant to run in parallel with an older system, superimposing with a high-pressure high-temperature forced-circulated boiler plant supplying back-pressure turbines would appear to be the answer. The thermal storage capacity of the low-pressure boiler plant would have to be relied on to meet emergency conditions.

AUTHOR'S REPLY

Mr. **Ungoed** wrote: The pre-war cost of fuel was so low in relation to plant production and capital costs that there was little incentive to achieve maximum thermal economy in industrial steam-raising plants. It is true that some of this outmoded opinion is still voiced today, but fortunately it is diminishing. The modern trend may err slightly on the conservative side, and aim at maximum reliability and freedom from trouble rather than peak thermal efficiency. It is difficult to strike any hard and fast dividing line between the two requirements. Most industrial steam and generating plants today are arranged on the 'topping set' system, where a low-pressure steam demand is supplied from high-pressure boilers through back-pressure or pass-out turbines.

N E W S



ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Changes on Council

The following have accepted invitations to serve as Honorary Members of Council during their periods of office:

Mr. W. M. LARKE, Chairman of the Engineering Committee

Mr. J. J. BEESE, President of the Ebbw Vale Metallurgical Society

Mr. C. E. BURRELL, President of the Leeds Metallurgical Society

Lieut. Commander G. W. WELLS, President of the Lincolnshire Iron and Steel Institute

Mr. G. T. CALLIS, President of the Liverpool Metallurgical Society

Mr. C. I. F. MACKAY, Chairman of the Newport and District Metallurgical Society

Professor H. O'NEILL, President of the Swansea and District Metallurgical Society.

Finland

Publication of the account of a visit to Finland in June, 1954, by a party of Members of the Institute has been deferred until a later issue of the *Journal*.

Autumn General Meeting, 1954

The **Autumn General Meeting** of The Iron and Steel Institute will be held at 4 Grosvenor Gardens, London, S.W.1, on **Wednesday and Thursday, 17th and 18th November, 1954.** The following is the detailed programme:

Wednesday, 17th November

Morning Session

9.45–10.15 A.M.—Formal business and election of Members

10.15–11.30 A.M.—Presentation and discussion of:

"*The Future of Steel Melting*," by M. W. Thring (*Apr.*, 1954)

11.30 A.M.—12.0 P.M.—Interval for light refreshments in the Library

12.0–1.15 P.M.—Presentation and discussion of:

"*The Problem of Rupture of the Billet in the Continuous Casting of Steel*," by J. Savage and W. H. Pritchard (*Nov.*, 1954)

1.15–2.30 P.M.—Buffet Luncheon in the Library

Afternoon Session

2.30–4.30 P.M.—Presentation and joint discussion of:

"*The Effect of Cold Work on the Gamma–Alpha Transformation in Some Iron–Nickel–Chromium Alloys*," by B. Cina (*Aug.*, 1954)

"*A Critical Investigation into the Ageing of Mild Steel Strip after Temper Rolling*," by B. Jones and R. A. Owen-Barnett (*June*, 1954)

"*Accelerated Strain-Ageing of Mild Steel*," by B. B. Hundy (*Sept.*, 1954)

"*Elimination of Stretcher Strains in Mild-Steel Pressings*," by B. B. Hundy (*Oct.*, 1954)

"*Yield-Stress/Strain Curves and Values of Mean Yield Stress of Some Commonly Rolled Materials*," by R. B. Sims (*Aug.*, 1954)

Thursday, 18th November

Morning Session

10.0–11.30 A.M.—Presentation and joint discussion of:

"*An Investigation of Reheating Furnace Design and Performance*," by F. A. Gray and S. H. Brooks (*Nov.*, 1954)

"*Internal Temperature Distribution in the Cooling and Reheating of Steel Ingots*," by R. J. Sarjant and M. R. Slack (*Aug.*, 1954)

11.30 A.M.–12.0 P.M.—Interval for light refreshments in the Library

12.0–1.15 P.M.—Presentation and joint discussion of:

"*The Length of Oil and Gas Flames—Extension of Free Flame Relationships to Practical Conditions*," by A. L. Cude (*Mar.*, 1954)

"*The Measurement and Influence of Preheat in the O.H. Furnace*," by W. P. Cashmore (*Oct.*, 1954)

1.15–2.30 P.M.—Buffet Luncheon in the Library

2.30–4.30 P.M.—Presentation and discussion of:

"*Fatigue Tests on Rolled Alloy Steels Made in Electric and Open-Hearth Furnaces*," by P. H. Frith (Special Report No. 50).

Symposium on Powder Metallurgy, 1954

The following is the complete list of papers submitted for the **Symposium on Powder Metallurgy,** to be held by The Iron and Steel Institute in association with the Institute of Metals at Church House, Westminster, London, S.W.1, on **Wednesday and Thursday, 1st and 2nd December, 1954:**

Group I—Manufacture, Properties, and Testing of Powders

"*Metal Powders for Engineering Purposes—A Review*," by W. D. Jones

"*The Grinding of Metal Powders*," by G. F. Hüttig and H. Sales

"*The Production and Fabrication of Tantalum Powder*," by R. Titterington and A. G. Simpson

"*The Powder Metallurgy of Zirconium*," by F. G. Cox and G. L. Miller

"*Powders for Magnetic Applications*," by G. R. Polgreen

"*Recent Developments in Testing Metal Powders*," by G. R. Bell

"*Application of Particle Size Analysis to the Quality Control of Metal Powders*," by V. T. Morgan

"*Determination of the Gas Contents of Materials of Powder-Metallurgy Practice*," by H. A. Sloman

"*Factors Influencing the Reactivity of Solids, with Particular Reference to Metals*," by J. A. Hedvall

Group II—Principles and Control of Compacting and Sintering

"*The Mechanism of Infiltration*," by P. Schwarzkopf
"*The Sintering Mechanism of Pure Metals, Including 'Activated Sintering,'*" by M. Eudier
"*The Variation of Thermo-Electric Force During Sintering*," by G. Ritzau
"*The Designation of Powders and Sintered Materials by Means of the Properties of the Pore Volume*," by K. Torkar and G. F. Hüttig
"*Pore Size Distribution and Permeability of Porous Metal Materials*," by P. R. Marshall
"*Filter Elements by Powder Metallurgy*," by V. T. Morgan
"*Relationships Between the Properties of Iron Powders and Powder Compacts*," by F. V. Lenel, H. D. Ambs, and E. O. Lomerson, jun.
"*Pressing Characteristics of Air-Atomized Copper Powder*," by A. Duffield and P. Grootenhuis
"*Grain Growth During Sintering*," by H. H. Hausner
"*The Hot-Compacting of Metal Powders*," by J. Williams
"*The Hot-Pressing of Ceramics*," by P. Murray
"*The Continuous Compacting of Metal Powders*," by P. E. Evans and G. C. Smith
"*Effect of Small Boron Contents on the Properties of Sintered Bodies Prepared by Vacuum Sintering*," by F. Frehn and W. Hotop
"*Sintering Furnace Atmospheres*," by L. D. Brownlee, R. Edwards, and T. Raine

Group III—Manufacture and Properties of Structural Engineering Components

"*Some Developments in Sintered Structural Parts*," by C. J. Leadbeater
"*Experiments on the Production of High-Strength Material and Parts by Powder Metallurgy*," by L. Harrison and S. Marton
"*Sintered Nickel Steel and Notes on Other Sintered Alloys*," by S. C. Wilsdon and P. J. Ridout
"*Solid Stainless-Steel Compacts from 18/8 Austenitic Powders*," by B. Sugarman
"*Porous Stainless Steel*," by D. A. Oliver, S. C. Wilsdon, P. R. Marshall, B. Sugarman, G. Collins, and C. T. J. Jessop
"*The Porosity and Air Permeability of Sintered Iron and Iron–Copper*," by C. J. Leadbeater and S. Turner
"*Low-Expansion Nickel–Iron Alloys Prepared by Powder Metallurgy*," by V. Thomas and D. J. Jones
"*Application of Powder Metallurgy to the Production of High-Permeability Magnetic Alloy Strip*," by E. V. Walker, D. K. Worn, and R. E. S. Walters
"*Fatigue Properties of Sintered Copper Compacts*," by O. J. Dunmore and G. C. Smith
"*Production of Sintered Copper–Lead Bearing Material*," by W. E. Duckworth
"*Properties and Testing of Sintered Copper–Lead Bearing Materials*," by P. G. Forrester and W. E. Duckworth
"*Fluon-Impregnated Self-Lubricating Bearing Materials*," by A. Blainey
"*Sintered Aluminium Powder*," by R. Irmann
"*Preparation of High-Modulus Aluminium Alloys by Powder Metallurgy*," by N. F. Macdonald and C. E. Ransley
"*Powder Metallurgy of Magnesium*," by D. J. Brown

Group IV—Powder Metallurgy of High-Melting-Point Materials

"*Developments in High-Density Alloys*," by E. C. Green, D. J. Jones, and W. R. Pitkin
"*The High-Temperature Strength of Some Co–Ni–Fe–Cr Base Materials Made by Powder Metallurgy*," by G. T. Harris and H. C. Child
"*Preparation and Properties of Titanium and Titanium Alloys Prepared by Sintering*," by D. A. Robins, W. R. Pitkin, and I. Jenkins
"*Sintered Titanium Carbide Alloys*," by E. M. Trent and A. Carter
"*The Testing of Ceramal Materials, with Particular Reference to a Simple Titanium-Carbide–Cobalt Material*," by T. W. Penrice and D. H. Shute
"*The Creep Strength of Titanium Carbide Base Materials*," by G. T. Harris, H. C. Child, and J. F. Howard
"*Silicides of the Transition Metals of the 4th, 5th, and 6th Groups of the Periodic Table*," by R. Kieffer and F. Benesovsky
"*Effect of Carbon Content on the Properties of Tungsten-Carbide–Cobalt Hard Metals*," by L. D. Brownlee, R. Edwards, and T. Raine
"*Chromium Carbide in Hard-Metal Alloys*," by J. Hinnüber and O. Rüdiger
"*Metal–Ceramic Bodies*," by A. E. S. White, F. K. Earp, T. H. Blakeley, and J. Walker
"*Development of Metal–Ceramics from Metal–Oxide Systems*," by J. R. Baxter and A. L. Roberts
"*The Rupture Strength of Some Metal-Bonded Refractory Oxides*," by G. T. Harris and H. C. Child

Preprints of the papers will be issued before the meeting, and afterwards the papers and discussion will be published in a bound volume of Proceedings. The price of the Proceedings is £3 5*s*. 0*d*. per volume (post free); in the case of orders received before the meeting one set of preprints will be provided free in respect of each bound volume ordered. Preprints will not be supplied without an order for a bound volume.

The Symposium is open to all interested in the subject, whether members of The Iron and Steel Institute or the Institute of Metals or not. A circular giving full details of the meeting has been sent to members of the two Institutes; non-members should apply to the Secretary of The Iron and Steel Institute for copies of the circular and reply forms.

Forgemasters

As previously reported, a joint meeting of the Chambre Syndicale de la Grosse Forge Française, the National Forgemasters Association and The Iron and Steel Institute is to be held at 4 Grosvenor Gardens, London, S.W.1, on **Tuesday and Wednesday, 12th and 13th October, 1954.**

The meeting will be divided into three sessions: Tuesday, 12th October, 9.45 A.M.–12.45 P.M. and 2.45 P.M.–5.15 P.M.; Wednesday, 13th October, 9.45 A.M.–12.45 P.M.

Among the papers to be presented for discussion by members of the National Forgemasters Association and of the Chambre Syndicale de la Grosse Forge Française are the following:

"*Problems in the Manufacture and Ultrasonic Inspection of Heavy Upset Forgings*," by C. Roques, Ch. Dubois, and P. Bastien (Société des Forges et Ateliers du Creusot)
"*The Manufacture of a Large Reaction Vessel in Ni–Cr–Mo Steel*," by E. de Kerverseau, A. Pierre, and P. Lamotte (Société des Forges et Ateliers du Creusot)

"*The New Firminy Forging Shop of the Société des Ateliers et Forges de la Loire*," by Monsieur Bois (Société des Ateliers et Forges de la Loire, Usine de Firminy)

"*The Continuous Grain-Flow Process and Its Recent Applications*," by Monsieur Verot (Société des Ateliers et Forges de la Loire, Usine de St. Chamond)

"*Reversible Deformation During Thermal Stability Testing of Rotor Forgings*," by H. H. Burton and J. E. Russell (English Steel Corporation Ltd.)

"*Trepan Boring with Special Reference to High Speed Deep Hole Boring Using Tungsten Carbide Tipped Tools*," by A. H. Bennett (Walter Somers Ltd.)

"*A 35,000-Ton Die-Forging Press for Light Alloys*," by J. G. Frith (Davy and United Engineering Co., Ltd.)

"*Heating and Soaking Times in Forge Furnaces*," by F. W. Jones and A. Barker (Thos. Firth and John Brown Ltd.).

Members of The Iron and Steel Institute are cordially invited to attend the technical sessions of this meeting. Further particulars may be obtained from the Secretary at 4 Grosvenor Gardens, London, S.W.1.

NEWS OF MEMBERS

▶ Mr. B. ARNOLD has been awarded the degree of B.Sc.

▶ Mr. T. C. BAILEY has been appointed Sales Manager of Shell-Mex and B.P. Ltd.

▶ Dr. C. S. BALL has relinquished his appointment as Lecturer in the Department of Industrial Metallurgy at the University of Birmingham, to become Assistant Chief Metallurgist to the Steel Division of the Steel Company of Wales Ltd.

▶ Mr. C. J. BARKER has been appointed General Managing Director of the Wellman Smith Owen Engineering Corporation Ltd., and Mr. F. H. BROOKS has been appointed Managing Director in charge of Production and Technical Development.

▶ Mr. N. CLARK, Managing Director of the Astbury Silica Co., has been elected President of the Refractories Association of Great Britain.

▶ Sir JOHN DUNCANSON, an Honorary Vice-President of the Institute, acted as Chairman of the Civilian Survey Mission formed by the Federation of British Industries, which visited Egypt at the request of the Government to study the future maintenance of the Suez Canal base by civilian contractors.

▶ Mr. J. DUNLOP has left the Lancashire and Corby Steel Manufacturing Co., Ltd., to join Armstrong Whitworth and Co. (Metal Industries), Ltd. He has recently paid a short visit to India.

▶ Mr. H. H. EGGINTON has been appointed Chief Engineer to the Refrigeration Division of the British Thermostat Co., Sunbury-on-Thames.

▶ Dr. A. E. EL-MEHAIRY has returned to Egypt to take up an appointment with the Ministry of Commerce and Industry in Cairo.

▶ Dr. P. FELTHAM has been appointed Lecturer in Physical Metallurgy at the University of Leeds.

▶ Mr. H. J. G. GOYNS of D. Drury and Co., Ltd., Johannesburg, immediate Past-President of the South African Branch of the Institute of British Foundrymen, is visiting the U.K. in order to study recent developments in melting plant and in foundry and rolling-mill equipment.

▶ Mr. J. B. HAWORTH has left the British Columbia Research Council to take up an appointment as Research Metallurgist with Sherritt Gordon Mines Ltd., Alberta.

▶ Mr. J. E. HOLGATE has been appointed General Manager of the Rhodesian Iron and Steel Commission.

▶ Mr. A. JACKSON, General Works Manager of the Appleby-Frodingham Steel Co., has been appointed a Director of the Company.

▶ Mr. J. F. B. JACKSON has relinquished his position as Director of the British Steel Castings Research Association, and has joined the Board of A.P.V.-Paramount Ltd. as Deputy Managing Director.

▶ Mr. S. T. JAZWINSKI has been appointed Director of Research to the following subsidiaries of the Barium Steel Corporation, New York: Central Iron and Steel Co., Phoenix Iron and Steel Co., and Chester Blast Furnace Inc.

▶ Mr. J. F. MILLS has transferred from the Summerfield Research Station of I.C.I. to Kynoch Works, Birmingham.

▶ Mr. J. S. MORTON has been appointed a Director of Electro-Chemical Engineering Co., Ltd.

▶ Dr. W. S. OWEN has left the University of Liverpool to join the Department of Physical Metallurgy of the Massachusetts Institute of Technology, U.S.A.

▶ Mr. N. B. PILLING has been appointed Assistant to the Vice-President of the International Nickel Co., Inc.

▶ Mr. S. V. RAMAN has left Germany for India, where he has been appointed Chief Metallurgist to the National Iron and Steel Co., Ltd.

▶ Dr. P. SAMUEL has left the Research Department of Hadfields Ltd. to become Senior Lecturer in Metallurgy at the Sheffield College of Commerce and Technology.

▶ Mr. A. G. SHAKESPEARE has left the English Electric Co., Ltd. to join the South Wales Laboratories of B.I.S.R.A. at Swansea.

▶ Mr. S. S. TALUJA has left Germany to return to India, where he has resumed his appointment as Technical Director of the S.P. Engineering Corporation, Kanpur.

▶ Mr. R. W. THOMAS has left K and L Steelfounders and Engineers Ltd., and has taken up an appointment as Senior Technical Engineer in the Engineering Development Laboratory, Aircraft Division, Bristol Aeroplane Co., Ltd.

▶ Mr. W. VICKERS has been awarded the degree of B.Met. of the University of Sheffield and is now a Research Student in Metallurgy at the University.

▶ Mr. W. B. WALLIS has received a Distinguished Alumnus Award of the Pennsylvania State University.

▶ Mr. C. A. E. WILKINS has rejoined the Anglo-Iranian Oil Co., Ltd., as Senior Metallurgist at the Aden Refinery.

▶ Mr. N. T. WILLIAMS has taken up an appointment with the Bristol Aeroplane Co., Ltd.

▶ Mr. A. B. WOODHEAD is at present carrying out his National Service, and has been granted a commission in the Royal Electrical and Mechanical Engineers.

Obituary

Mr. JAMES CAMPBELL, formerly Chairman of the Northern Mercantile and Investment Corporation Ltd., on 4th September, 1954.

Mr. FREDERICK GRANT, Q.C., Independent Chairman of the British Iron and Steel Federation, on 19th Sept., 1954, aged 64.

Mr. E. F. MACTAGGART, formerly of the Sondes Place Research Institute, Dorking, on 27th August, 1954.

Mr. C. H. PLANT, of Walsall, Staffs., in February, 1954.

Dr. H. A. SCHWARTZ, formerly Manager of Research to the National Malleable and Steel Castings Co., Ohio, U.S.A., aged 74.

Mr. P. H. WILSON, O.B.E., Deputy Managing Director of the Stanton Ironworks Co., Ltd., on 25th July, 1954.

Corrigendum

It was stated on p. 257 of the June, 1954, issue of the *Journal* that Mr. M. D. Patwardhan had been awarded the degree of Ph.D. of the University of Leeds. The name should have read Mr. M. K. Patwardhan.

CONTRIBUTORS TO THE JOURNAL

William Banks—Blast-Furnace Manager to Colvilles Ltd., Clyde Iron Works, Glasgow.

W. Banks

Mr. Banks was born at Maryport, Cumberland, in 1914, and was educated at the County Technical and Secondary School, Workington. He joined the Workington Iron and Steel Co. in 1931 as a Student Apprentice. In 1939 he was transferred to the Appleby-Frodingham Steel Co. where he remained until 1945, when he returned to Workington. In the following year he joined the Cargo Fleet Iron Co., Ltd. He took up his present appointment in 1949.

A. R. Chaudhuri, B.Sc., Ph.D.—Research Associate in the Department of Metallurgy, Massachusetts Institute of Technology, U.S.A.

Dr. Chaudhuri was born in India and received his early education there, graduating from the University of Calcutta in 1946. He then came to the U.K. and worked under Professor F. C. Thompson at Manchester University, where he was awarded the degree of Ph.D. in 1951. In the same year he joined the High-Temperature Group of the Department of Metallurgy at the Massachusetts Institute of Technology. He has since been working under Professor N. J. Grant on the mechanisms of deformation of metals during creep.

(Dr. Chaudhuri is the co-author of a paper published in the September issue of the *Journal*.)

H. M. Richardson, B.Sc., F.R.I.C.—Principal Scientific Officer, British Ceramic Research Association.

Mr. Richardson was born in 1913. He was educated at the Liverpool Collegiate School and at Liverpool University, where he graduated with Honours from the Chemistry School. On leaving the University in 1935 he joined the British Refractories Research Association (now the British Ceramic Research Association), and has remained on the research staff since then. He has carried out research on the action of gases, alkali vapours, and iron, calcium, and manganese oxides, etc., on refractories, and has studied the mineralogical composition of refractories by the X-ray diffraction method. His main interests at present are the acid and basic refractories used in the iron and steel industry.

D. Thomas, M.A.—Assistant Fuel and Refractories Officer with the Park Gate Iron and Steel Co., Ltd.

Mr. Thomas was educated at Mexborough Grammar School and at Oriel College, Oxford University, where he was awarded a 2nd Class Honours degree in Physics in 1948. During the war he served as a Technical Officer in the R.N.V.R. After a post-graduate course at Standard Telephones and Cables Ltd., and a period of employment with Ferodo Ltd., Mr. Thomas joined the Steelmaking Division of the British Iron and Steel Research Association in 1951. He was later appointed Senior Scientific Officer, and during this period he was concerned with industrial experimentation, particularly on open-hearth furnaces. He took up his present appointment at the end of 1953.

IRON AND STEEL ENGINEERS GROUP

The **Twenty-Seventh Meeting** of the Iron and Steel Engineers Group will be held at 4 Grosvenor Gardens, London, S.W.1, on **Thursday, 9th December, 1954.** Two papers will be presented for discussion; one on Cold Rolling of Strip by T. W. Hood, and one on Wire Drawing Equipment by H. Richards.

Full details of the programme will be given in a later issue of the *Journal*.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Eighth Chemists' Conference

The Eighth Chemists' Conference of the Association will be held at Swanwick, Derby, on Tuesday and Wednesday, 12th and 13th October, 1954. The programme will comprise the presentation and discussion of papers on the following subjects: Chromatographic separation techniques; analytical chemistry of boron; silica in blast-furnace slag and related materials; titanium in iron and steel; vanadium in iron and steel; spectrographic analysis of slags; separation and identification of inclusions in steel.

Open Days at Battersea

The work of the London Group of the Association's Laboratories will be exhibited at the Battersea Laboratories, 140 Battersea Park Road, London, S.W.11, on Thursday and Friday, 18th and 19th November, 1954. Members of the Institute are cordially invited to visit the Laboratories. Those who require luncheon and tea tickets are asked to apply to the Information Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

Corrosion Advice Bureau

The Association has recently formed a Corrosion Advice Bureau, in order to deal adequately with the numerous enquiries that are received for advice on the prevention of corrosion of ferrous metals. Dr. J. C. Hudson has been appointed Head of the Bureau, which will be situated at Battersea, and Mr. E. E. White will be Secretary. Dr. W. H. J. Vernon has been engaged as Consultant.

The services of the Bureau will normally be free to members of the Association, They will also be available to others on a fee-paying basis depending on the extent of the investigations required.

Dr. T. E. Dancy

Dr. T. E. Dancy has returned to B.I.S.R.A. after 14 months as Metallurgical Liaison Officer with the United Kingdom Scientific Mission in Washington, D.C., and has been appointed Commercial Development Officer at Headquarters. In this appointment he will be responsible to the Secretary for progressing the exploitation of the Association's patents and for liaison with research staff with a view to selecting those projects which might find commercial application outside the steel industry.

EDUCATION

Course in Electro-Chemistry—Liverpool

A post-graduate course on "*Modern Developments in Electro-Chemistry*" will be held by the University of Liverpool, commencing on 8th October, 1954. The course, which comprises 20 evening lectures and is open to graduates in chemistry, metallurgy, or engineering, or persons holding comparable qualifications, will deal mainly with the study of the mechanism of the processes occurring at electrodes during electrolysis. The fee for the course of lectures, which will be held in the Department of Chemistry of the University, is 4 gns. Tickets for the course may be obtained either from the Director of Extra-Mural Studies, 9 Abercromby Square, Liverpool, 7, or at the opening meeting.

School of Physical Metallurgy—Sheffield

The Postgraduate School of Physical Metallurgy of the University of Sheffield will organize courses of one or two weeks' duration during the present session, in the hope that more metallurgists from industry will be able to attend. Lecture courses will be separated from the associated advanced practical work and discussions, so that students may attend the first half only, although it is recommended that they attend both courses if possible. Courses have been arranged on the following subjects: Metallurgical techniques, deformation of metals, physical metallurgy of heat-treatment, alloy theory of steels, internal stresses, and annealing of cold-worked metals. Further information and application forms for the whole session or for separate courses may be obtained from the Registrar, The University, Western Bank, Sheffield, 10.

NEWS OF SCIENCE AND INDUSTRY

Discussion on Use of Slags—Brussels

The Association Belge pour Favoriser l'Étude des Verres et des Composés Siliceux is organizing a discussion on the use of slags for road making, runways, and aerodromes, etc. The meeting will be held at 242 rue de la Loi, Brussels, during the week commencing 19th October, 1954. Communications from British authors will be welcome.

Verein deutscher Eisenhüttenleute

The annual Eisenhüttentag of the Verein deutscher Eisenhüttenleute will be held in Düsseldorf on 4th–5th November, 1954.

Robert Horne Memorial Lecture

The Second Robert Horne Memorial Lecture of the Society of Chemical Industry will be given by Dr. Maurice Cook at University College, Swansea, on 30th November, 1954, under the title "*Metallurgical Progress and the Chemical Industry.*" Members of the Institute are cordially invited to attend the meeting.

Conference on Micro-Analysis and Determination of Trace Elements—Dusseldorf

The Chemical Research Committee of the Verein deutscher Eisenhüttenleute is holding a Conference on Micro-Analysis and Determination of Trace Elements to be held on 1st October, 1954. Chairman of the Conference, which will be held at the Eisenhüttenhaus, 27 Breite Strasse, Düsseldorf, will be Dr.phil. P. Dickens. The programme is as follows: 10.0 A.M.—"*Microanalytical Determination and Separation of Trace Elements in Iron,*" by H. Malissa (Düsseldorf); "*Spectrographic Determination of Trace Elements without Previous Separation,*" by W. Koch (Düsseldorf); "*The Use of the Optical Pyrometer for Determination of Trace Elements after Concentration,*" by H. Specker (Dortmund). 3.0 P.M.—"*The Determination of Boron in Steel,*" by H. G. Short (N.P.L., Teddington); "*Rapid Determination of Small Quantities of Carbon in Steels and Alloys,*" by K. Abresch (Duisburg-Hamborn); "*Exact Rapid Micro-Analysis of Gases,*" by H. Feichtinger (Balzers, Liechtenstein); "*Trace Analysis, Using Radioactive Isotopes,*" by W. Herr (Mainz). Members of the Institute are welcome at the meeting.

Gift to University College of Swansea

Richard Thomas and Baldwins Ltd. have recently made a gift of £100,000 to the University College of Swansea. Half of the gift is to be used to establish an additional Chair in the Department of Metallurgy, and half will be used to furnish new laboratory equipment in connection with the Chair.

D.S.I.R.—New Chairman of Advisory Council

The Lord President of the Council of the Department of Scientific and Industrial Research has appointed Sir Hugh Beaver, Managing Director of Arthur Guinness, Son and Co., Ltd., to be Chairman of the Advisory Council for Scientific and Industrial Research. Sir Hugh succeeds Professor Sir Ian Heilbron, who retired on 30th September, on completion of his term of office.

Roll Makers' Association

Mr. F. Trehearne Thomas has been appointed Chairman of the Roll Makers' Association of Great Britain. The Association has recently formed a Research Organization, and Mr. E. V. Parkinson has been appointed Technical Secretary. The address of the Secretaries of the Association and of the Research Organization is Lombard House, Great Charles Street, Birmingham, 3.

Visits to Electric Furnace Works

Visits to the Watford works of Wild-Barfield Electric Furnaces Ltd. are being arranged for senior engineering students and members of technical societies from September, 1954, to May, 1955. Visitors will be able to tour the production shops, metallurgical and chemical laboratories, and the development section of the works. Anyone wishing to take part in the visits is asked to apply as soon as possible to the Company at Elecfurn Works, Watford, Herts.

Ore-Handling Plant

A contract valued at about £1 million, for a new ore-handling plant at the Cardiff works of Guest Keen Iron and Steel Co., Ltd., has been secured by the Moxey Conveyor and Transporter Co., Ltd., Birmingham. This is probably the largest single ore-handling contract ever placed in this country, and comprises equipment for the handling of iron ore at the rate of 1500 tons/hr. from dockside cranes to main storage bunkers and thence to the crushing plant, screening station, and finally blast-furnace bunkers or stockyard. The plant, which also includes the conveying, crushing, and screening of limestone, basic slag, and coke, will have a total length of belt conveyors of about 2 miles. The consulting engineers for the plant are the International Construction Co., Ltd.

Properties of Nimonic 95

Nimonic 95 is a recent addition to the Nimonic series of alloys, and an extensive survey of properties, particularly long-time creep properties, has not yet been possible. However, it has been found that the greatest creep-resistance is normally obtained by solution-treating the alloy at as high a temperature as possible, but this can sometimes lead to the development of a coarse grain size, depending on the conditions of the prior hot-working. The recommended treatment which gives good creep properties and retains a fine grain size over a wide range of hot-working conditions is as follows: 4 hr. at 1150° C., A.C., followed by 6–8 hr. at 1080° C., A.C., followed by 16 hr. at 700° C., A.C.

Initial solution-treatment for 1–2 hr. at 1200° C. instead of 4 hr. at 1150° C. has been used when a coarser grain size has not been regarded as unsatisfactory, the later steps of the treatment remaining unchanged.

Details of the properties obtained with these treatments may be obtained from Henry Wiggin and Co., Ltd., Wiggin Street, Birmingham, 16.

Changes of Name and Address

GUEST KEEN BALDWINS IRON AND STEEL CO., LTD., will in future be known as Guest Keen Iron and Steel Co., Ltd.

The offices of the Liège Section of the CENTRE NATIONAL DE RECHERCHES MÉTALLURGIQUES have removed to l'Université de l'Etat à Liège, 'Abbaye du Val-Benoit,' Liège, Belgium.

The office of the NEWCOMEN SOCIETY is now at the Science Museum, Exhibition Road, London, S.W.7 (Tel. Kensington 1793).

The address of the INSTITUTION OF MECHANICAL ENGINEERS is now known as 1 Birdcage Walk, Westminster, London, S.W.1 (Tel. Whitehall 7476-9).

The JOHN THOMPSON GROUP of Companies has opened a new Branch Office, which will be operated from "Ravenswood," Westfield Lane, Ryton-on-Tyne, Co. Durham.

CUPODEL LTD., of Birmingham, specialists in hot-blast equipment for cupolas, have, as from 1st April, 1954, become associated with Keith Blackman Ltd. The registered office of Cupodel Ltd. is now at Mill Mead Road, Tottenham, London, N.17, and the Birmingham office is at 1294 Bristol Road South, Northfield, Birmingham 31.

HONEYWELL-BROWN LTD. have recently established an additional Glasgow office at 26 Blythswood Square, Glasgow.

THE AUSTRO-AMERICAN MAGNESITE CO. and THE INTERNATIONAL MAGNESITE CO.—Mr. A. Samson, agent for Gt. Britain for the above firms, has removed to new premises at 2 Madeira Mansions, Atlantic Road, Weston-super-Mare (Tel. 6411).

The head office of the GLENBOIG UNION FIRE CLAY CO., LTD., has removed from Glasgow to Glenboig, Lanarkshire (Tel. Glenboig 421).

The business of Mr. F. V. WRIGHT, Consulting and Designing Engineer, has removed from Wednesbury to 31 Queen Street, Wolverhampton. The full title of the business will now be F. V. Wright and Partners.

METAL INDUSTRIES LTD. has removed to new premises at Universal House, 60–62 Buckingham Palace Road, London, S.W.1 (Tel. Sloane 5587, 5814, and 5618).

THE RENOLD AND COVENTRY CHAIN CO., LTD., will in future be known as Renold Chains Ltd. The address of the Company is now Renold House, Wythenshawe, Manchester (Tel. No. Gatley 5221).

Industrial Publications Received

▶ M.R.I.—a brick that can halve your furnace maintenance (Ref. No. RD42): M.I.28—a brick for increased output with lower fuel consumption (Ref. No. RD43): M.I.23—a brick for low fuel costs (Ref. No. RD44). Morgan Crucible Co., Ltd.

▶ "*Why Productivity?*" is the first of a series of pamphlets issued by the British Productivity Council with the aim of discussing techniques for a continuous increase in productive efficiency. Copies may be obtained direct from the Council, or through booksellers, price 1*s*.

▶ Micro-focus X-ray unit—Publication No. CH 356/2—Compact 3-metre grating spectrograph—Publication No. CH 331/2—Hilger and Watts Ltd.

▶ Brochure on the G.P. Centralized Lubrication System—Ref. No. 654—Tanway Ltd.

▶ Brochure on Wiggin Nickel Alloys gives details of their application to the electrical and engineering industries and to the manufacture of jet engines, instruments, etc.—Henry Wiggin and Co., Ltd.

▶ Brochure on the Uvispek photoelectric spectrophotometer—Publication No. CH 318/9—Hilger and Watts Ltd.

CORRIGENDUM

Theory of Hydrogen Embrittlement

In the second paragraph (p. 85) of the paper by F. de Kazinczy (*J. Iron Steel Inst.*, 1954, vol. 177, pp. 85–92) the term "maximum tensile stress" should be taken as the maximum ratio between tensile force and original sectional area, and "ultimate tensile stress" as the ratio between tensile force and true (contracted) sectional area at fracture, *i.e.*, the true stress at fracture.

Some Factors Affecting the Wear of Graphite Electrodes

The following corrections should be made to the paper by the Electric Process Sub-Committee (*J. Iron Steel Inst.*, 1954, vol. 176, Feb., pp. 159–165):

Throughout the paper, resistivity should be expressed in microhm-cm. On p. 162, the formula for calculating resistivity should be $V\pi r^2/Il$.

DIARY

1st Oct.—MAX-PLANCK INSTITUT FÜR EISENFORSCHUNG—Conference on Microanalysis—Düsseldorf, Germany.

6th–7th Oct.—INSTITUTE OF FUEL—Conference on "*A Special Study of Sulphur Removal and Recovery from Fuels*"—Institution of Mechanical Engineers, Birdcage Walk, London, S.W.1.

12th–13th Oct.—Joint meeting of the Comité de la Grosse Forge Française, the National Forgemasters Association and The Iron and Steel Institute—4 Grosvenor Gardens, London, S.W.1.

12th–13th Oct.—BRITISH IRON AND STEEL RESEARCH ASSOCIATION—Eighth Chemists' Conference—The Hayes, Swanwick, Derby.

12th–14th Oct.—ENGINEERING INDUSTRIES ASSOCIATION—London Regional Display.

13th Oct.—NORTH WALES METALLURGICAL SOCIETY—"*The Melting, Refining and Casting of Copper*," by H. J. Miller—County Primary School, Plymouth Street, Shotton, Chester, 7.15 P.M.

15th Oct.—NEWPORT AND DISTRICT METALLURGICAL SOCIETY—Annual Dinner—King's Head Hotel, Newport.

18th Oct.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—"*Metallurgical Problems of Atomic Energy*," by L. Rotherham—University Building, St. George's Square, Sheffield.

25th–30th Oct.—SOCIÉTÉ FRANÇAISE DE MÉTALLURGIE—Autumn Meeting—Paris.

1st–5th Nov.—AMERICAN SOCIETY FOR METALS—36th National Metal Congress and Exhibition—Chicago, U.S.A.

3rd Nov.—COKE OVEN MANAGERS' ASSOCIATION—Annual technical meeting—London.

4th Nov.—COKE OVEN MANAGERS' ASSOCIATION—Annual General Meeting—Waldorf Hotel, Aldwych, London, 2.30 P.M.

TRANSLATION SERVICE

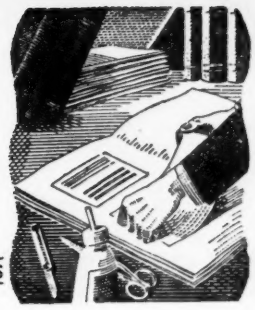
(The previous announcement was made in the September, 1954, issue of the *Journal*, p. 68).

TRANSLATIONS IN COURSE OF PREPARATION

(German). A. KEIL: "Should One Use Solid or Segmented Resin Bearings in Rolling Mills?" (*Die Technik*, 1953, vol. 8, Sept., pp. 609–612).

(German). H. WIRTZ: "The Sampling of Ferro-Alloys and Their Ores." (*Archiv für das Eisenhüttenwesen*, 1954, vol. 25, May–June, pp. 225–230).

ABSTRACTS OF CURRENT LITERATURE *and* BOOK NOTICES



IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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MINERAL RESOURCES

The Liassic Ironstones. T. H. Whitehead, W. Anderson, V. Wilson, D. A. Wray, and K. C. Dunham. (*Department of Scientific and Industrial Research, Memoirs of the Geological Survey of Great Britain*, 1952). This 211-page volume is one of a series of memoirs setting out the results of work on the Mesozoic iron ores conducted by the Geological Survey since 1939. Four ironstone fields are dealt with : (*a*) Liassic iron ores of Cleveland ; (*b*) Frodingham (lower Lias) Ironstone of Lincolnshire ; (*c*) Marlstone Rock-Bed ironstone of Lincolnshire, Leicestershire, and Rutland ; and (*d*) Marlstone Rock-Bed Ironstone of N. Oxfordshire, S.-W. Northamptonshire, and S.-E. Warwickshire.—R. A. R.

Recent Chromite Exploration in Shetland. J. B. Rivington. (*Min. Mag.*, 1953, **89,** Dec., 329–337). Details are given of the production of chromite at Unst from 1820 until 1944 when surface deposits became exhausted. Extensive bore-hole surveys have failed to reveal new concealed ore-bodies, but it is believed that they have escaped detection.—K. E. J.

The Mineral Resources of the Jura. V. Charrin. (*Genie Civil*, 1954, **131,** Feb. 15, 67–70). Concerning iron ores, several deposits 3–4 m. thick exist but the iron content seldom exceeds 35%. Although large reserves of iron oxides exist throughout the Jura it is unlikely that they will be utilized.

What Do We Know About Our Reserve Deposits? C. Hahne. (*Glückauf*, 1954, **90,** Mar., 13, 316–318). The present state of knowledge of the German reserve coal deposits is discussed.—L. D. H.

Some Aspects of Latin American Coal Reserves. J. D. Price. (*Amer. Inst. Min. Met. Eng., Proc. Blast Furn. Coke Oven Raw Mat. Comm.*, 1953, **12,** 158–181). The more important factors concerning the coal reserves of the eight major Latin American countries are described in detail. (35 references).—B. G. B.

Location of the Minerals of Iron, Carbon and Calcium which Are of Use to the Iron and Steel Industry of Colombia. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct.13–Nov. 5, 1952, *Paper* L.28). [In Spanish].

A Realistic Look at Taconite Estimates. J. W. Gruner. (*Min. Eng.*, 1954, **6,** Mar., 287–288).

The Problem of Fluorspar Supply. R. E. Holmes. (*Batelle Tech. Rev.*, 1953, **2,** Dec., 133–135). A summary of present and future uses of fluorspar is given and some production problems are mentioned.—R. P.

Manganese in Bombay State, India. (*Min. J.*, 1954, **242,** Apr. 2, 389–390 ; Apr. 9, 417). A short account of mining operations carried out by nine manganese mining lease holders in Bombay State is given, together with details of the deposits in this region.—B. G. B.

Geology and Mineral Deposits of Jumbo Basin, Southeastern Alaska. (*Geological Survey Professonal Paper* 251 : U.S. Government Printing Office, 1953). This is a discussion of the contact metamorphism, geomagnetic surveys, magnetite deposits, and iron ore reserves of part of Prince of Wales Island.—R. A. R.

Iron Deposits at Fort Gouraud, Mauritania, French West Africa. F. R. Lethbridge and F. G. Perceival. (*Trans. Inst. Min. Met.*, 1953–54, **63,** Mar., 285–298). The occurrence of high grade hematite ore is described and the geology and mode of formation of the deposits are discussed. An outline is given of the exploration campaign with references to problems of climate, transport, and labour as well as possibilities of exploitation.—E. C.

Metallurgy in Morocco. (*Min. J.*, 1954, **242,** Apr. 30, 508). A very brief account of the mining and metallurgical industries of Morocco is given. About 600,000 tons of iron ore are produced each year.—B. G. B.

Iron Oxides from the Marrakech Region. G. Vié. (*Écho Mines*, 1954, Feb., 91–94). A description of the Kettara mining area in North Africa is given. The iron ore produced is a hematite containing 51–52% Fe, with 11–13% SiO_2 and 0·03% P and the annual production is 60,000 tons. Details of the geology of the district and of the mining methods used are given.—B. G. B.

ORES—MINING AND TREATMENT

Iron Ore in Canada. A. Buisson. (*Min. Mag.*, 1954, **90,** Apr., 201–202). In 1953, output exceeded consumption for the first time, at 5,804,500 long tons, and it will increase during 1954. A review is given of mining and process developments at Three Rivers, Steep Rock, Wabana, Allard Lake, Marmora, Algoma, and Iron Hill.—K. E. J.

Sub-Level Caving at Grängesberg, Sweden. B. K. Lundin. (*Min J.*, 1954, **142,** Feb. 19, 204–206, 236–238). A description of mechanical caving as practiced at the Grängesberg iron ore field in Sweden is given.—B. G. B.

Exploitation of the Kiruna Iron Ores, Sweden. J. B. Richardson. (*Min. J.*, 1954, **142,** Mar. 26, 361–363). An account of the geological formation of the ore and of the methods of mining and transportation used, are given. The ore is hauled direct from the mine to Narvik, Norway.

Magnetite Pelletizing and the Production of Sponge Iron. (*Min. Mag.*, 1954, **80,** Feb., 75–78). Details are given of the

plant at Bodås of the Sandvikens Jernverks A.B. It produces 60,000 tons of concentrates per year from a 40% Fe magnetite ore. The new plant produces pellets in a rotary drum ; these are then sintered at 1100–1200° C. in an oil-fired shaft furnace, the output being 100 tons per day. The pellets are used to produce sponge iron by the Wiberg process.

The Sintering Plant of Monlevade. F. J. Pinto de Souza. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, Paper L. 33). [In English]. A description of the Monlevade (Brazil) sintering plant in which charcoal fines are used as a fuel is given together with some operating data.—V. G.

The Preparation of the Burden of Blast-Furnaces Using Lorraine Minette Ores. P. Thierry. (*Mét. Constr. Mécan.*, 1954, **86,** Feb., 87–91). The practice of sintering Lorraine minette ores on a Dwight-Lloyd sintering machine is described. Details of the preparation of the raw materials, addition of moisture and mixing, ignition, cooling, and screening are given. The moisture content of the mixture is controlled so as to give the optimum permeability of the bed ; the amount of water added varying with different materials.—B. G. B.

Quality Control of Blast Furnace Flue Dust Sinter. E. C. Rudolphy and D. J. Carney. (*Amer. Inst. Min. Met. Eng., Proc. Blast Furn. Coke Oven Raw Mat. Comm.*, 1953, **12,** 18–52). A detailed account of work carried out on a Dwight-Lloyd sinter plant at the South Works of the United States Steel Corporation, is given. A sample of the sinter was obtained by placing a stainless steel frame on the stand close to the swinging spout and removing it at the end of the strand after sintering. The sample obtained was subject to strength, reducibility and microscope tests and these are described in detail. Factors influencing the strength and reducibility of the sinter were investigated. (17 references).—B. G. B.

Sintering Fans—Construction and Application. H. R. Phelps. (*Amer. Inst. Min. Met. Eng., Proc. Blast Furn. Coke Oven Raw Mat. Comm.*, 1953, **12,** 81–103). Constructional details and performance data for sintering fans are discussed. A constant speed motor with a variable fluid drive has advantages over a variable speed motor. The construction of cyclones is also dealt with.—B. G. B.

Iron Ore Preparation and Blast Furnace Operation of Japan. T. L. Joseph. (*Tetsu to Hagane*, 1951, **37,** Aug., 481–489). [In Japanese]. Results of laboratory tests and surveys of operating data are used to illustrate the main principles of ore preparation and furnace operation.—K. E. J.

Studies on Contact Angle Measurements and their Application to the Concentration of Manganese Ores by Froth Flotation: Part I—Contact Angle Studies at the Pyrolusite Surface. Part II—Beneficiation of Low-Grade Manganese Ores by Froth Flotation. U. N. Bhrany and M. R. A. Rao. (*J. Sci. Indust. Res.*, 1953, **12,** Dec. 590–604). The effects of time, *p*H, and temperature on the contact angle at the pyrolusite surface have been investigated employing oleic, stearic, and palmitic acids as collectors. The contact angle is found to have an exponential relationship with temperature in the case of saturated fatty acids. The difference in the behaviour of saturated and unsaturated fatty acids has been explained on the basis of two centres of adsorption in the oleic acid molecule. The conditions of flotation have been standardized for the beneficiation of a finely divided silicious pyrolusite ore. Optimum conditions for the flotation of this ore have been worked out by a detailed study on the flotation variables and a concentrate containing 53·1% Mn, 10·6% SiO_2, and 3·73% Fe_2O_3 is obtained. The recovery of manganese is 88·5%.—J. O. L.

Modernized Mineral-Dressing Laboratories at the Royal School of Mines, London. J. K. Almond. (*Iron Coal Trades Rev.*, 1954, **168,** Mar. 26, 729–738). The author describes the layout and equipment of the recently modernized mineral-dressing laboratories of the Royal School of Mines, and outlines the reasearch work now in progress.—G. F.

FUEL—PREPARATION, PROPERTIES, AND USES

Fuel Research in Great Britain. A. Parker. (*IVA.*, 1953, **3,** Aug. 24, 92–103). A review of work carried out in the field of fuel research by universities, research stations and in industry is presented. (13 references).—R. P.

Relative Fuel Values. (*Indust. Gas*, 1954, **17,** Apr., 195–198). Three sources of power, electricity, gas, and oil, are compared with regard to rate of heating, cleanliness, service, and economy.—D. H.

Thermal Conductivity Chart for Gases. A. I. Johnson and Chen-Jung Huang. (*Chem. Eng.*, 1954, **61,** Feb., 204–205). A chart is presented which facilitates the determination of the thermal conductivity of gases when the specific heat and viscosity are known.—R. A. R.

The Efficient Use of Gas in Industry. W. F. Howell. (*Fuel Economist*, 1953, **1,** Dec., 83–86). The author considers that maximum efficiency is not being obtained from existing appliances and that too many badly-designed or badly-adjusted appliances are in use. He advocates making fuller use of the free advisory service provided by Gas Boards.—R. P.

The Combustion of Gaseous Suspensions of Coke Particles. Z. F. Chukhanov and A. P. Chirkin. (*Doklady Akademii Nauk S.S.S.R.*, 1954, **94,** (6), 1069–1072). [In Russian]. An attempt to deduce an approximate method for the theoretical calculation of the combustion of gaseous coke suspensions is given.—V. G.

Transport of Momentum, Mass, and Heat in Turbulent Jets. L. G. Alexander, T. Baron, and E. W. Comings. (*Illinois Univ. Eng. Exper. Sta. Bull. Series No.* 413, 1953, **50,** May, 7–88). A method based on Reichardt's hypothesis of momentum transfer is described, and is shown to be useful and accurate for complex cases of the transport of heat, mass, and momentum in free jets. The extension of Reichardt's hypothesis to mass and heat transfer is proposed and the extended hypothesis is compared with experimental data from single free jets. The transport of momentum from multiple parallel jets and from a jet issuing parallel to a wall is described. The applications to evaporation from a spray of liquid droplets and to combustion in a similar case are discussed. (76 references).—L. E. W.

New Facilities for Flame Radiation Research: Inauguration Ceremony at Ijmuiden. (*Brit. Steelmaker*, 1954, **20,** May, 178–180). For the purposes of the international flame radiation research at Ijmuiden, a new furnace, with many improvements, has been built and housed in a new research building equipped with pump house, instrument room, gas analysis section, and other specialized equipment. A description of the new plant and equipment is given with details of the proposed plant for the study of pulverized fuel firing.—G. F.

Flame Lengths: Estimation for Coke Oven Gas and for Oil. J. A. Leys. (*Iron Steel*, 1954, **27,** Mar., 93–94). The author develops simple equations for calculating the lengths of flames of fuel oil and coke-oven gas. The case of combined flames of the two fuels is discussed, and the equation for flame length in this case is given in general form. The effect of steam/oil ratio is also considered.—G. F.

The Determination of the Velocity of Flame Propagation. A. van Tiggelen and J. Vaerman. (*Bulletin des Sociétés Chimiques Belges*, 1953, **62,** Oct.-Dec., 653–660). After discussing the limitations of existing methods for determining the velocity of flame propagation, the authors describe a new technique; this is based on the measurement of the density and temperature of the flame front. The main advantage of this method is its independence of the shape of the flame.—R. P.

Automatic Electric Control in a Boiler Control Room. Namy. (*Centre Doc. Sid., Circ. Inform. Tech.*, 1953, (9), 1439–1447). Electric regulation is not applicable where large thermal inertia exists but it has the advantages of rapid response and flexibility in comparison with pneumatic or oil systems. The characteristics and principles of automatic regulation are discussed in relation to the installation in a modern boiler house.—A. G.

Ultrasonic Flue Dust Elimination. H. Manley. (*Engineer*, 1954, **197,** Feb. 19, 291). After a brief description of the precipitation of smoke particles by an ultrasonic beam of frequencies from 100 down to 20 kilocycles/sec., the author describes industrial applications of ultrasonic generations and sirens which are used to precipitate brass and aluminium foundry smokes, soda-ash fumes, sulphuric acid mist, cement flue dust, carbon black furnaces, zinc furnaces, and oil mists.

Centrifugal Dedusting. S. W. Muhlrad. (*Chaleur et Ind.*, 1954, **35,** Feb., 41–58). A theoretical account of the movement of gas and the pressure drop in cyclones is given. Examples of calculating performance from formulæ are discussed. The conditions and limitations of the employment of ordinary cyclones and various multi-tubular devices are considered. Difficulties may arise from condensation, inadequate centrifugal speed, hygroscopic dusts, electrostatic charges, etc. Finally, different kinds of equipment are described and

the possibility of dedusting by several types of cyclone in series is mentioned.—A. G.

Atmospheric Pollution: Causes, Effects, and Prevention. A. Parker. (*Proc. Inst. Civil Eng.*, 1954, **3,** Apr., 99–124). The author discusses the nature and amount of pollution from the use of fuels, and presents the results of relevant investigations with brief details of the techniques and instruments developed. It is concluded that grit, smoke, oxides of sulphur, and carbon monoxide have the greatest deleterious effects. The need for more intensive research is stressed.

Atmosphere Pollution Interim Report of the Beaver Committee. (*Gas Times*, 1953, **77,** Dec. 11, 412, 414). The mains points of the interim report are discussed, and the Committee's recommendations for avoiding the worst effects of ' smog ' are given in detail.—B. C. W.

Topographical Influences on Dispersal of Stack Gases. G. H. Strom and J. Halitsky. (*Australasian Eng.*, 1953, Dec. 7, 68–70). The two factors which control the path followed by stack gases are (*a*) velocity and temperature of gas at exit from stack, and (*b*) air motion, which is determined by meteriological factors and surface topography. These factors are discussed with reference to experiments in the wind tunnel at New York University, and it is concluded that counter measures to topographical disturbances may be found in plant architecture, and layout.—P. M. C.

The Calculation of the Basic Data for the Washability Diagram. K. Lemke. (*Glückauf*, 1954, **90,** Apr. 24, 449–454). A method is described of applying the coal characteristics and those of the washing plant to the construction of washability curves.—L. D. H.

Technical Aspects of Application of Electric Equipment in Coal Preparation Plants. W. R. Morton. (*Trans. Amer. Inst. Elec. Eng.*, 1953, **72,** Part II, 349–355).

Considerations in Coal Washing in Europe and Its Possible Application to Latin American Coals. C. Cheradame. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.1). [In English].

Problems in the Preparation of Metallurgical Coal in Latin America. T. Fraser. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, Paper L.2). [In English].

Notes on the Production of Metallurgical Coal in Brazil. Alvaro de Paiva Abreu. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.5). [In English].

Description of Chilean Coals Used in the Steel Industry. Alfredo Gonzales. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.6). [In English].

Improving Coking Qualities of Coal by Addition of Various Materials. A. R. Powell. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.15). [In English]. The individual stages of the carbonization process affecting the physical properties of cokes are outlined. Methods used for improving coke properties with particular reference to blending techniques are reviewed. Tests on the effect of various blending additions to a charge of low-rank coals are described.—V. G.

Correlation of Small-Scale Carbonizing Tests with Commercial Coke-Oven Results. A. R. Powell. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.16). [In English]. The correlation of the properties of coke obtained from small-scale carbonization tests with those of commercially produced cokes is discussed. It is concluded that a fairly accurate estimate of coke properties can be made on the basis of small scale tests.—V. G.

Argentine Asphaltites As Blending Material for Poorly Coking Coal. A. R. Powell. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.17). [In English].

Production of Metallurgical Coke in Mexico. Salvador Cortés Obregón. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.20). [In English].

Metallurgical Coke from Chilean Coals. Americo Albala. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.21). [In English].

Coal Washery Performance as Related to Blast Furnace Costs. J. D. Price. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.26). [In English]. A method of estimating the optimum point to which it is economical to reduce ash content of a coking coal by washing is described.—V.G.

The Problem of Energy for Iron and Steel Works. G. Périn. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.58). [In Spanish]. An outline is given of a steelworks' power requirements and some comparison is made of the uses made of coal gas, blast-furnace gas, and a mixture of the two.—C. B. L.

The Status of Coal Cleaning in Western Canada. J. Visman. (*Trans. Canad. Min. and Met.*, 1954, **47,** Jan., 13–21 ; *Bull.*, 15–23). The importance of quality in marketing West Canadian coals is discussed in relation to coal cleaning practice. The performance of various jigs, pneumatic tables, counter-flow air tables and other cleaning equipment is considered and compared.—A. G.

Cleaning Fine Coal in a Feldspar Jig at Brazeau. A. McMullen. (*Canad. Min. and Met. Bull.*, 1954, **47,** Feb., 86–89). Details are given of the operation of a feldspar jig treating $-\frac{3}{8}$-in. coal fines. The plant is mechanically reliable and the results of sink-and-float tests on the product are reported. For this fine coal with associated friable refuse, the ideal solution would be one re-wash jig for a series of primary jigs.

TEMPERATURE MEASUREMENT AND CONTROL

Temperature Measurements by Means of Fluorescent Materials. P. Brauer. (*Z.V.d.I.*, 1954, **96,** Mar. 21, 285–287). Use can be made of the sudden variation of luminosity with temperature for the purpose of temperature measurement. The advantages are reversibility of the phenomenon and speed of response. The principles are discussed and examples of the use of suitable fluorescent points are given.

High Temperature Measurement. A. E. Turner. (*Coventry Eng. Soc. J.*, 1954, **35,** Jan.-Feb., 3–16). The author traces the development of quantitative pyrometry and deals with the standardization of temperature measurement before proceeding to a consideration of pyrometry in industry. The applications, optimum operating temperature ranges, and general limitations of base metal, rare metal, and refractory metal thermocouples, and optical, total radiation, and partial radiation pyrometers are discussed.—L. E. W.

A Rapid Photographic Method for the Measurement of Flame Temperature Based on the Reversal of Spectral Lines. G. H. Young and P. A. Tyler. (*Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique des Products Métallurgiques, 15th Congress*, June, 1952, 83–95). *See J. Iron Steel Inst.*, 1954, **177,** July, 383).

REFRACTORY MATERIALS

Reduction in the Loss Factor of Certain Ceramics by Heat Treatment. H. Rawson. (*Nature*, 1954, **173,** Mar. 6, 447). The effect on dielectric losses in steatite and forsterite after 60 hr. heat-treatment has been studied. In most cases a reduction in the tangent of the loss angle was observed which may be due to a decrease in the number of lattice defect pairs or to divitrification of the glassy phase.—A. G.

Carbon As a Structural Material. A. E. Williams. (*Indust. Heating Eng.*, 1954, **16,** Feb., 35–39). The author first traces briefly the developments in the production of a carbon suitable for structural purposes. The modern material depends for its strength on a single-phase structure. Coking coal is finely ground, mixed with swell inhibitors, pressed or extruded to the desired shape, and then fired in such a temperature cycle as will give maximum shrinkage without distortion. Some uses of carbon as a structural material are described and illustrated by photographs. The high compressive strength, impermeability, and accurate machinability of carbon enable it to be used for heat exchangers. Its self-lubricating features make it an excellent material for bearings, and

for compressor components where a supply of oil-free gas is needed. Piston parts in contact with carbon rings should be made from rust-resisting metal. Mention is made of carbon block furnace hearths and porous carbon for use in gas dispersal.—L. E. W.

Heat-Loss Graph Aids in Specifying Most Economical Insulation Thickness. (*Indust. Heating*, 1954, **21**, Mar., 563–566). Nomograms are given from which, knowing the hot surface temperature and fuel cost, the most economical insulation thickness can be calculated.—R. W. B.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

New Blast Furnace: Lighting Ceremony at Appleby-Frodingham. (*Iron Steel*, 1954, **27**, Apr., 124). Brief details are given of the new blast-furnace with a 27-ft. hearth recently brought into service at Appleby-Frodingham Steel Co. It is expected to produce 6000 tons/week.—G. F.

John Summers & Sons Limited—Ironmaking Plant. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 25–45, 106). Following a general outline of the layout of the new blast-furnace and ore preparation plant at John Summers & Sons Ltd., full details are given of the materials handling plant, the sintering plant, and the blast-furnace together with its subsidiary equipment. The electrical equipment, including the electrostatic precipitators, is also considered. The furnace is believed to be the largest outside the U.S.A.—G. F.

John Summers & Sons Limited—Blower House and Power Plant. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 61–65, 195). The main plan of the new blower house and power plant at John Summers & Sons Ltd., consists of a turbine house and boiler house on two main levels, and an annexe containing the control rooms. The construction of the plant is described, and details are given of steam generation, turbo-alternators and turbo-blowers, control boards, heating and ventilating, and dust extraction and vacuum cleaning.

Use of Brazilian Ore in the Blast Furnace. J. R. Lowe. (*Amer. Inst. Min. Met. Eng., Proc. Blast Furn. Coke Oven Raw Mat. Comm.*, 1953, **12**, 145–147). The replacement of steel scrap in the burden of the Eliza blast-furnaces of Jones and Laughlin Steel Corporation, U.S.A., by a pure hematite ore (68·22% Fe), mined near Itabera in Brazil, and the changes in practice which have resulted from this are described.

The Blast-Furnace Operation with Hokkaido Coal-Made Coke. T. Onoda. (*Tetsu to Hagane*, 1951, **37**, Feb., 71–77). [In Japanese]. As a result of difficulties in importing coking coals, Wanishi Iron Works is using local high-volatile coal. This produces a coke with a drum-test strength of 50–60%, which is satisfactory for a 225 ton/day furnace. Blending with 25% of coalite produces a coke-strength of 80%, which leads to a daily output of 600 tons from a larger furnace rated at 700 tons/day.—K. E. J.

Investigations on Taphole Clays and Taphole Practice. W. Banks and H. M. Richardson. (*J. Iron Steel Inst.*, 1954, **178**, Oct., 138–146). [This issue].

Integrated Electrical Equipment for Blast Furnace Operation. C. P. Hamilton. (*Iron Steel Eng.*, 1954, **31**, Apr., 89–93 : *Steel*, 1954, **134**, Feb. 22, 113–119). The author describes recent developments in the electrical equipment which have helped to make blast-furnace operation automatic. Power distribution and utilization are considered as well as the essential drive units, programme control, distributor operation, and plant maintenance.—M. D. J. B.

Development of Steelworks Instruments. D. W. Gillings. (*Blast Furn. Steel Plant*, 1954, **42**, Apr., 434–442). Details of a number of instruments for use on blast-furnace and sinter plants are given.—B. G. B.

Instrumentation for Blast Furnace Research. D. I. Sinizer, J. DePiccolellis, and E. R. Poor. (*Amer. Inst. Min. Met. Eng., Proc. Blast Furn. Coke Oven Raw Mat. Comm.*, 1953, **12**, 318–325). Two instruments for use on blast-furnaces are described. The first is a slip recorder which measures the duration and intensity of the slip. The second is a gas analysis apparatus to measure continuously the volume percentages of CO, CO_2 and hydrogen in the gas. It is claimed that the direction of fluctuation in hearth temperature and the analysis of the iron in the next succeeding cast can be made from the top gas analysis; it is also suitable for detecting water leaks.—B. G. B.

Thoughts on Metallurgical Processes. S. Eketorp. (*Tekn. Tidskr.*, 1954, **84**, Apr. 13, 325–330). [In Swedish]. New methods and equipment proposed and used during the last ten years for ore mining, concentration, and especially smelting are discussed. General hints are given on blast-furnace practice and a scheme is illustrated whereby the material will flow continuously from the mine through the steelworks to emerge as a finished rolled product.—G. G. K.

Contributions to the Study of Conditions for Good Distribution of Materials in the Blast-Furnace. J. Vibrac. (*Mét. Constr. Mécan.*, 1953, **85**, Sept., 685–693 ; Oct., 773–777 ; Nov., 851–861 ; 1954, **86**, Jan., 11–19 ; Feb., 92–97 : *Iron Coal Trades Rev.*, 1954, **148**, Apr. 16, 911–916 ; Apr. 23, 957–962). The importance of good distribution of materials in the blast-furnace is stressed. The relative thickness of the ore and coke layers at various radial positions in the throat are related to the angles of repose of the materials, the volumes of materials charged and the stockline contour. The effect of moisture upon the angles of repose is discussed. Factors affecting the voidage of a bed of particles of mixed size and the influence of these upon the channels available for passage of gas through the bed are considered. The relationship between the permeability and the voidage of the bed is discussed. The effect of the size distribution of the stock, layer thickness and type of charging (*i.e.*, lateral, intermediate or central) upon the permeability of the stock column is considered. An equation for the trajectory of materials falling from the bell is developed and the influence of stockline height, bell/throat diameter ratio, and bell angle upon stockline contour is dealt with. The effect of stockline height upon the critical top gas velocity is considered. The influence of the height of materials in the hopper, the bell overhang, bell drop, and speed of opening of the bell on the distribution of materials is discussed together with the problem of compensated charging.—B. G. B.

Distribution of Burden Materials in a Blast Furnace Model. R. L. Stephenson and F. C. Langenberg. (*Amer. Inst. Min. Met. Eng., Proc. Blast Furn Coke. Oven Raw Mat. Comm.*, 1953, **12**, 265–280). The results of an investigation of the distribution of ore and coke during charging, carried out primarily on models but also on full size furnaces, are given. The results obtained on the full size furnaces agree with those of the models. Among the variables examined are ore size, stockline height, and charging cycles.—B. G. B.

Contribution to the Study of Coke Consumption in the Blast-Furnace. M. Brun and J. Szczeniowski. (*Rev. Mét.*, 1954, **51**, Mar., 154–164). A method of controlling blast-furnace operation is described, based on the useful heat of the coke U, which depends on the calorific value of the coke and of the gas produced from it, the blast temperature, and the sensible heat of the top gas. Equations relating U to the heat of chemical reactions, the heat in iron and slag, and losses, for different types of furnace operation, are derived which permit graphical control of the coke rate and the calculation of burden adjustments.—A. G.

Preheating and Blowing-In Practice at the Blast Furnace. R. J. Wilson. (*Amer. Inst. Min. Met. Eng., Proc. Furn. Coke Oven Raw Mat. Comm.*, 1953, **12**, 216-225). An account of the blowing-in practice used by the Inland Steel Co., U.S.A. is presented. Full details of the operations of drying-out, cooling off, filling, putting on the blast, casting, and burdening are given. Particular attention is paid to the amount of limestone required to bring the sulphur in the iron into the desired range as the silicon is lowered.—B. G. B.

Blowing-In Practice at American Steel and Wire Division, Duluth Works. W. A. Abbett, jun. (*Amer. Inst. Min. Met. Eng., Proc. Blast Furn. Coke Oven Raw Mat. Comm.*, 1953, **12**, 230–235). A detailed account of the blowing-in practice at this American plant is given. In order to improve the heating of the hearth, the hot blast blown in through the tapping hole is removed through an improvised pipe in the slag notch instead of out of the top. Additional air is obtained by opening the tuyeres on the opposite side to the slag notch.

Blast Furnace Blowing-In and Drying-Out Practices, Bethlehem Plants. H. M. Kraner. (*Amer. Inst. Min. Met. Eng., Proc. Blast Furn. Coke Oven Raw Mat. Comm.*, 1953, **12**, 236–245). The drying-out and blowing-in practices at the Bethlehem plants vary considerably and the methods used at each are presented in tabular form. Half of the 32 furnaces at these plants have carbon linings.—B. G. B.

PRODUCTION OF STEEL

Flame Radiation and Open Hearth Productivity. M. W. Thring. (Cleveland Inst. Eng.: *J. Iron Steel Inst.*, 1954, **178,** Oct., 165–169). [This issue].

Measurement and Influence of Preheat in the Open-Hearth Furnace. W. P. Cashmore. (*J. Iron Steel Inst.*, 1954, **178,** Oct., 112–121). [This issue].

Radioactive Measurement of Valve Leakage, Infiltration, and Blowout in Open-Hearth Furnaces. E. B. Bell and D. Thomas. (*J. Iron Steel Inst.*, 1954, **178,** Oct., 122–126). [This issue].

Reports by Industrial Teams and Quantity-Measuring Technicians on Open-Hearth Furnaces in the East German Republic. (*Met. u. Giesserei Techn.*, 1954, **4,** Feb., 77–84). Several criticisms are made of the design and operation of open-hearth furnaces in East Germany.—R. A. R.

On the Combustion in the Open-Hearth Furnace Heated by the Producer Gas (II). Y. Doi. (*Tetsu to Hagane*, 1951, **37,** Feb., 81–87). [In Japanese]. By the use of an air jet type port which introduces compressed air and gives a Bunsen burner type of flame, the velocity of combustion is increased, and a short sharp flame results. Melting times are reduced by 20%, and fuel consumption by 15%. Flame direction and speed are easily controlled.—K. E. J.

Study on the Combustion of Producer Gas in Open Hearth Furnace. (III). Y. Doi and K. Tasaka. (*Tetsu to Hagane*, 1951, **37,** Sept., 450–455). [In Japanese]. In a venturi type acid furnace, the combustion velocities were determined by CO analysis of the flame gas. Velocity constants were found for gas with 15% excess air (13), additional air blowing (37) and oxygen blowing (66).—K. E. J.

Study of Slag Specimens Taken from Charges Blown in a Basic-Bessemer Converter without Lime Additions. P. Kozakevitch and P. Leroy. (*Rev. Mét.*, 1954, **51,** Mar., 203–209). In the absence of lime the initial slag is acid and rich in iron, containing 15 to 40% of iron partly in a dispersed form. After 16 min. the slag is basic, homogeneous, and iron-free. The larger iron globules have a lower carbon and higher phosphorus content than the melt. The emulsifying power of the slag diminishes with increasing lime content. Acid slags are frothy and stiffened by the presence of metallic globules. This pasty mass hinders the passage of air and contributes to swelling of the charge.—A. G.

Standard Dimensions of Gas Fired Open-Hearth Furnaces. Y. Doi. (*Tetsu to Hagane*, 1951, **37,** Apr., 239–243). [In Japanese]. After the war, the Maerz-type furnaces in Japan were criticized, and ideal dimensions have been recommended for producer-gas-fired basic fixed venturi-type furnaces of 40, 50, 60 and 80-ton capacities for the cold charge scrap process.

Cost Comparisons of the Open Hearth and Electric Furnace. D. D. Moore. (*Iron Steel Eng.*, 1954, **31,** Mar., 55–65). This paper, which summarizes a comprehensive study made by the Battelle Memorial Institute, evaluates the present and potential competitive aspects of the electric-furnace and open-hearth processes in making low-carbon steels. (10 references).

New 10-Ton Arc Furnace for Darwins. (*Brit. Steelmaker*, 1954, **20,** Apr., 140–142). A new 10-ton swing-roof Efco-Héroult arc furnace has recently been installed at the Andrews Toledo works of Darwins Ltd., Sheffield. It is powered by a 3500 kVA. transformer fed from the works 11,000-V. supply. Constructional details of the furnace are given.—G. F.

PRODUCTION OF FERRO-ALLOYS

Production of Electrolytic Manganese. N. Dhananjayan, H. K. Chakrabarti, and T. Banerjee. (*J. Sci. Indust. Res.*, 1954, **13,** Feb., 136–144). The results of experiments on the production of manganese using a canvas diaphragm cell, stainless steel anode and lead cathodes show that optimum conditions for electrolysis are : C.d. 26·4 amp./sq. ft. ; temperature, 32°–35° C. ; manganous sulphate in the feed electrolyte, 80 g./l. ; ammonium sulphate 150 g./l. ; sulphur dioxide, not less than 0·15 g./l. ; catholyte *p*H, 7·2. Variables of the process have been investigated.—J. O. L.

Recovery of Manganese in Steel Mill Operations. E. C. Wright. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1953, 123–145). The author outlines a method for the concentration of manganese from low-manganese materials, such as low-grade ores and open-hearth slags. The materials are smelted in a blast-furnace to give hot metal with 4–5% Mn, which is partly oxidized in a converter to give a slag with 50% MnO and 40% SiO_2. This material is then used to produce silicomanganese and different grades of ferromanganese. The economics of the process are examined and its introduction into integrated plant practice is discussed.—G. F.

Characteristics of Slags Obtained in the Production of Ferromanganophosphorus in the Blast Furnace. A. L. Zagyanskii. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **83,** (2), 265–267). The influence of slag composition and furnace temperature on the transfer of manganese and phosphorus to the metal during the production of ferromanganophosphorus was investigated. It is concluded that during the production of high-phosphorus ferro-alloys under normal temperature conditions (silicon in metal 0·4–0·7%) it is desirable to use slags with a lime/silica ratio of 1·5–1·55. Such basicity ensures 60% manganese recovery from a comparatively lean ore and 89% phosphorus recovery from the usual phosphites.—V. G.

Utilization of Ferro-Alloys. M. Royer. (*Centre Doc. Sid., Circ. Inform. Tech.*, 1953, (8), 1259–1271). The causes of loss when using ferro-alloys are examined. In electric steel-making, alloying elements may be lost to the slag or hearth or by volatilization. Slag losses are minimized by a low volume, high basicity, and high temperature. The behaviour of tungsten, molybdenum, vanadium, and cobalt is considered in particular.—A. G.

Electrical and Electrometallurgical Industries of Canada. III. Ontario and Manitoba. A. C. Holm. (*J. Electrochem. Soc.*, 1954, **101,** Feb., 41c–49c). Brief descriptions of all plants manufacturing ferro-alloys and electric steel in Ontario and Manitoba are given.—A. D. H.

FOUNDRY PRACTICE

The Use of Hot Blast Cupolas. (*J. Inform. Tech. Indust. Fonderie*, 1954, Feb., 1–2). The advantages of using a hot blast (300–400° C.) in cupola operations are considered. These include increased rate of production, lower fuel consumption, less manganese and silicon loss, and reduction in the sulphur content. The construction of recuperators is also considered.—B. G. B.

Hot Blast Cupolas. B. Thyberg. (*Gjuteriet*, 1954, **44,** Feb., 19–28). [In Swedish]. After describing cupola designs in which the exit gases are used for preheating the blast, the author discusses operating experience at Husqvarna since 1952. Results show that coke consumption, melting loss of silicon and manganese, and sulphur pick-up have been reduced, while melting rate and carbon pick-up have been increased. These facts outweigh the disadvantage of higher capital costs (£30,000 for conversion of 12-ton/hr. unit to hot blast), depreciation, and maintenance. Several hot-blast systems are illustrated and discussed. These include the Vereinigte Ekonomiser Werke recuperator, Schack's new spiral recuperator, the Inka recuperator, and the Philipon furnace.—G. G. K.

Some Observations on Oxygen in Cast Iron. T. Kinoshita and M. Nakashima. (*Tetsu to Hagane*, 1951, **37,** July, 420–426). [In Japanese]. The use of the hot-blast cupola has reduced many troubles experienced with cast iron. Cracks, deficiencies in strength and impact value, and variations in the graphite structure can be related to the FeO content of the iron.

Melting Unbriquetted Turnings in a Cupola. Yu. S. Sukharchuk and M. P. Nikolaïchik. (*Liteĭnoe Proizvodstvo*, 1954, (1), 30–31). [In Russian]. Full-scale experiments on the melting of loose turnings in a cupola are described in which various methods of securing adequate permeability of the charge, satisfactory quality of cast iron and efficient operation were investigated. When melting steel turnings without ferro-alloy additions an iron suitable for the production of grey or malleable cast iron was obtained, and relationships were found between the sulphur, silicon, and silicon plus carbon contents. When melting cast-iron turnings, losses of 20% of the carbon, 50% each of silicon and manganese, gains of 12–14% of sulphur and no changes in the phosphorus were observed.—S. K.

Deslagging when Pouring Iron Castings. (*Fonderie*, 1953, Dec., 3728–3730). Illustrated details are given of the various slag traps that can be used with castings of different sizes, particular castings weighing more than 100 lb.—B. C. W.

Hardened Cast-Iron Rolls for Rolling Mills. O. Nečas. (*Hutnické Listy*, 1954, **9,** (2), 34–43 ; (3), 72–74). [In Czech].

The manufacture, properties, composition, structure, hardenability, and heat-treatment of chill-cast rolls of all types used in rolling mills are considered in detail. The effects of various amounts of alloying elements, in particular nickel, chromium, tellurium, and vanadium on the structure and quality of rolls is discussed with particular reference to graphitization, hardenability, hardness and segregation. Methods of melting the iron, casting, rates of cooling of the ingots, ageing, limits of sulphur and phosphorus contents, mould design, and mould dressing, and other details of metallurgical control are surveyed. The author thinks that chill-cast iron rolls will not be replaced by steel rolls even in the future, though improvements in their properties may result from the use of nodular cast irons and from developments in the production of duplex cast rolls.—P. F.

Effect of Tellurium and Boron on Cast Iron. T. Tanaka, and A. Muramatsu. (*J. Mech. Lab.*, 1953, **7**, Nov., 249–255). [In Japanese]. Both elements have been found effective in increasing the depth of chill. Balanced proportions of tellurium and graphite give a distinct chill surface backed by a comparatively narrow zone of mottled iron. Boron additions offer a means of saving chromium in Ni–Cr alloyed chilled rolls without sacrifice of depth and hardness of chill.

Notes on the Hardness of White Irons. (*J. Inform. Tech. Indust. Fonderie*, 1953, Nov.-Dec., 8–9). Factors influencing the hardness of white irons are considered. These include the influence of total carbon and chromium, and the optimum carbon content to obtain maximum hardness for various nickel and chromium contents. Methods of obtaining white irons with a Brinell hardness between 300 and 700 are described.—B. G. B.

Wear-Resisting Grey Iron—Conditions for Casting It and Judging Its Quality. H. Ringpfeil. (*Met. u. Giesserei Techn.*, 1954, **4**, Apr., 157–163). The effects of static and dynamic friction upon iron castings are described ; wear-resistant cast iron is defined ; the various methods of producing it are discussed at length, and methods of testing the quality of wear-resistant cast iron are outlined.—L. J. L.

Cast Iron with 5–8% Silicon. (*Fonderie*, 1954, Jan., 3778). The properties, uses, and methods of manufacture of cast iron containing 5–8% silicon are briefly described.—B. C. W.

Developments in Foundry Production by S. Russell and Sons, Ltd., Leicester. (*Machinery*, 1954, **84**, Feb. 19, 380–382). This company has recently marketed under licence spheroidal graphite iron castings as ductile iron. The iron constituent may vary from fully pearlitic, as in high-carbon steel, to fully ferritic, as in mild steel, or, by heat-treatment or alloying, a wide range of properties can be obtained.—M. A. K.

Desulphurization in the Treatment of Cast Iron with Magnesium. K. I. Vashchenko, P. V. Abrinskiĭ, and B. M. Pashkovskiĭ. (*Liteĭnoe Proizvodstvo*, 1954, (1), 9–14). [In Russian]. After a consideration of the thermodynamic relationships involved in the treatment of cast iron with magnesium an account is given of experiments in which the desulphurizing action of this element was investigated. Samples of the iron were tested with magnesium at various temperatures (1300–1600° C.) followed by standing for 10–100 min. Desulphurization was also studied under production conditions in a 500-kg. ladle. Specimens of inoculated irons were examined microscopically and with the aid of sulphur prints. Distribution coefficients for carbon, silicon, manganese, phosphorus, sulphur, and magnesium between iron and slags of various compositions were measured.—S. K.

On the Formation of Graphite in Cast Irons Inoculated with Magnesium. K. P. Bunin and Yu. N. Taran. (*Doklady Akdemii Nauk S.S.S.R.*, 1954, **94**, (6), 1061–1063). [In Russian]. The mechanism of growth of graphite inclusions is discussed. It is assumed that the process controlling the rate of growth and the shape of graphite inclusions is the removal of the atoms of iron in the austenite from the front of graphite segregation. As the space in the austenite is freed it is filled with carbon atoms thus leading to the growth of graphite inclusions. Magnesium as a surface active element concentrates on the grain boundaries slowing down the migration of iron atoms across the boundaries and therefore graphitic inclusions do not attain the branched shape characteristic of ordinary malleable cast irons. It is concluded that the processes in the metallic matrix removing iron atoms from the surface of graphite inclusions determine the shape of the latter.

Malleablizing of Cast Iron Treated with Magnesium. M. Okamoto and T. Tottori. (*Tetsu to Hagane*, 1951, **37**, Oct., 520–523). [In Japanese]. Small amounts of magnesium produce mottled structures, but spheroidal graphite is formed with >0·6% Mg. Magnesium tends to chill the iron, and to retard graphitization during annealing. Malleable iron is rapidly formed by annealing iron containing sufficient carbon and silicon, after treatment with magnesium ; high phosphorus iron may be used for making ductile iron and the range of section size of the castings is increased.—K. E. J.

Researches on Austenitic Malleable Cast Iron. (I). N. Tsutsumi. (*Tetsu to Hagane*, 1951, **37**, Sept., 480–484). [In Japanese]. Research was directed to the production of blackheart malleable iron by single stage annealing. Addition of manganese produces an austenitic matrix, but the carbon remains as free carbide. However, annealing at 950° C. for 40–60 hr. in a reducing or neutral atmosphere graphitizes all the free carbide.—K. E. J.

A Study of Malleable Cast Iron Containing Copper and Aluminium. T. Mishima, T. Mitsuhashi, and T. Tanaka. (*Tetsu to Hagane*, 1951, **37**, May, 302–306). [In Japanese]. Aluminium additions markedly reduce the time for first-stage graphitization and the tensile strength and elongation, and they affect the graphite shape. They reduce fluidity, but this is restored by copper additions. The optimum mechanical properties are obtained by precipitation hardening after first-stage graphitization.—K. E. J.

Control of the Annealing of Cast Iron by Magnetic Properties. K. P. Zhadnov. (*Liteĭnoe Proizvodstvo*, 1954, (1), 29–30). [In Russian]. Tests on specimens of white iron showed that the residual magnetic induction satisfactorily characterizes both ferrite content and hardness. A simple apparatus for the control of annealing based on this relationship is described.

Steelmaking in an Electric Arc Furnace for Foundry Production. W. Siddle. (*Anvil*, 1954, **3**, Spring, 13–16). The author describes broadly the conducting and non-conducting-hearth arc furnaces used in steelmaking. The types of refractory linings commonly used are indicated and charging is dealt with briefly. He concludes with a description of the basic process with particular reference to the function of the slag and the removal of phosphorus and sulphur.

Cost Factors in Electric-Furnace Operation. F. S. Leigh. (*Found. Trade J.*, 1954, **96**, Mar. 18, 293–296). The direct-arc, low-frequency induction, and high-frequency induction furnaces are briefly described and their applications outlined. The capital costs and the operating costs for both melting and holding are compared for each furnace, and show that the low-frequency furnace is the less expensive and, for a given output per hour, the high-frequency furnace is the more expensive.—B. C. W.

Steel Castings Production: Shop Practice at Darwins, Ltd., Foundry. (*Iron Steel*, 1954, **27**, Feb., 43–47 ; Mar., 89–91). The foundry of Darwins Ltd., Sheffield, has separate flow-lines in the same shop for mechanized, stack, and jobbing moulding with a variety of alloy steels. Following an outline of the melting facilities, details are given of the layout and practice in each of the moulding divisions.—G. F.

Cast Steel. P. Berger. (*Arts et Manuf.*, 1954, Jan., 35–37). The present state and the activities of the French steel castings industry are reviewed. Examples of work carried out are given and the use of cast steel in welded constructions is discussed. The advantages of cast steel construction over other methods are considered.—B. G. B.

Mechanization of Production Processes in a Steel Foundry. P. O. Belov and L. E. Shul'man. (*Liteĭnoe Proizvodstvo*, 1954, (1), 24–27). [In Russian]. An account is given of the mechanization in a steel foundry of operations involved in the preparation of moulds and the transport of materials.—S. K.

Preparation and Casting of Metals and Alloys under High Vacuum. J. D. Fast, A. I. Luteijn, and E. Overbosch. (*Philips Tech. Rev.*, 1953, **15**, Oct., 114–121). An apparatus is described in which metals and alloys of extreme purity and precise composition can be produced in a form that lends itself well to further shaping into test specimens or components. Induction melting and casting are accomplished under high vacuum, the water-cooled tapered copper mould ensuring solidification from the bottom upwards and the absence of blowholes. The high degree of purity obtainable is demonstrated by chemical analysis of iron, microphotographs of an 80/20 Ni–Cr alloy, and the magnetization curve of a 40/60 Ni–Fe alloy.—P. M. C.

What the Designer Must Know Concerning the Effect of Solidification and Cooling on the Production of Sound Steel Castings. A. Hencks. (*Rev. Tech. Luxembourg.*, 1954, **46,** Jan.-Mar., 1–16). The physical changes occurring during the solidification and cooling of steel castings are considered with reference to the production of sound steel castings. Factors influencing the formation of shrinkage cavities, segregation, linear contraction and formation of cracks are discussed. The correct design of castings is reviewed and eight rules which should be followed are given. (10 references).—B. G. B.

On the Surface of Steel Castings. H. Nisihara. (*Tetsu to Hagane*, 1951, **37,** Aug., 473–477). [In Japanese]. Comparisons were made of the roughness of castings produced in painted and unpainted moulds, and factors influencing this were elucidated.—K. E. J.

Thermit Casting. J. Steele. (*Inst. Brit. Found., Engineer and Foundryman*, 1954, **18,** Mar., 70–74). The thermit process, by means of which molten steel at temperature of approximately 2400° C. is produced by a rapid chemical reaction between iron oxide (millscale) and powdered aluminium, is described. Quantities ranging from a few pounds to a ton may be produced, and the operation may be carried out wherever desired. The set-up of equipment for foundry use and in the field is illustrated. Full details are presented of the application of the process to casting and other foundry work, and a summary of the economic and practical aspects of thermit casting production is given.—P. M. C.

Foundry Trends. J. Stirling. (*S.A.E. J.*, 1953, **61,** Dec., 23–27). This is a condensed version of the Foundry Panel's discussion at the S.A.E. National Production Meeting, in March 1953.—P. M. C.

Why Sand Control? C. A. Sanders. (*Found. Trade J.*, 1954, **96,** Feb. 11, 165–168). The reasons for introducing sand control into a foundry, the functions of a sand control laboratory, and the results to be expected from it are discussed.

Measurement of the Pressure Operating on the Surface of Iron Castings in Solidification. H. Nagao. (*Tetsu to Hagane*, 1951, **37,** Oct., 517–519). [In Japanese]. The pressure of the gas on the surface of iron and aluminium is related to the casting temperature, the moisture in the sand, sand permeability, and casting thickness. It should be small to ensure sound castings.—K. E. J.

On the Volume Change of Sand Mould with Drying. H. Nisihara. (*Tetsu to Hagane*, 1951, **37,** Jan., 17–22). [In Japanese]. That part of the expansion or contraction of sand moulds which persists after cooling was particularly studied ; the percentage of moisture was the major governing factor.—K. E. J.

Synthetic Moulding Sand and Its Use in the Grey Iron Foundry. K. Houben. (*Giesserei*, 1954, **41,** Feb. 18, 81–86). After an introductory discussion on natural and synthetic moulding sands the methods of testing sand at normal and high temperatures are described. An investigation is described in which testing is carried out on temperature-stressed sand and Bentonite. The properties of the different sands, such as permeability to gas, are given up to temperatures of 1000° C. The use of synthetic sand in the foundry is illustrated by examples and the advantages described.—R. J. W.

On the Gradings of Core Binders on the Basis of Laboratory Investigations. A. Pack. (*Giesserei*, 1954, **41,** Jan. 21, 33–38). The different methods of testing core binders are described, followed by a description of a physical-chemical investigation carried out in the laboratory on seven different binders (oily and oil free) used in conjunction with different sands, to make blends and green and dry cores. The mixtures and cores with the binders which showed the best results were compared with one another. Works experiments confirmed the laboratory results.—R. J. W.

Differences Between Sand and Chill-Cast Hematite Iron and the Possibilities of Controlling the Structure of Chill-Cast Pigs. J. Willems, W. Lückerath, and H. Schroer. (*Giesserei*, 1954, **41,** Jan. 7, 7–13). Changes that take place in the melt, such as the separation of kish-graphite and slag particles during the conveyance of the pig iron to the casting machine are first considered. The effect of casting in sand or chill-casting on the texture are considered separately and compared. Texture formation in cast iron is followed and illustrated by numerous micrographs. By lowering the speed of cooling, a ferritic-pearlitic structure is obtained, whilst with a higher rate of cooling, a pearlitic-martensitic structure follows. The effect of such changes on other properties, such as the hardness, is discussed, and the possibility of controlling the structure of the chill-cast pigs is considered.—R. J. W.

Plastic Patterns. W. C. H. Dunn. (*Canad. Metals*, 1954, **17,** Jan., 26–29). The uses and advantages of thermosetting plastics for the production of foundry patterns, are described.

Improving Casting Yields—Insulation of Iron and Steel Risers. D. E. Brooks. (*Iron Steel*, 1954, **27,** Apr., 131–132). In a series of experiments on the insulation of risers for iron and steel castings, the most satisfactory material is a mixture of sawdust, dextrine and water, which is mulled, formed, and dried before use. The advantages and disadvantages of these riser sleeves are listed.—G. F.

The Clamping of Moulding Boxes. A. Knickenberg. (*Giesserei*, 1954, **41,** Feb. 18, 97–98). The methods of clamping moulding boxes employing clamps and wedges are illustrated. Examples are shown of the correct angle for the wedges employed. This angle should not exceed 10°. Screw clamps with hand levers and extensions are briefly described. An adjustable American clamp and a Swedish clamp are described and their dimensions given.—R. J. W.

Mechanical Moulding Boxes, Considered from the Tolerance View-Point. K. Rüster. (*Giesserei*, 1954, **41,** Jan. 7, 21–23). In the manufacture of delicate and thin-walled machine-moulded castings, the manner in which the two halves of the box are held together is very important. The tolerances permissible in 'peg-in-slot' joints and in the subsequent defects in the casting are considered, numerical examples being given. The use of tension pegs is illustrated and the merits of this device are listed.—R. J. W.

The Use of Compressed Air and the Efficiency of Press Moulding Machines. W. Gesell. (*Giesserei*, 1954, **41,** Feb. 4, 57–62). The methods used to control and measure the use of compressed air in a works are described. Numerous indicator diagrams are given, both theoretical and practical, which show the effect of compression with and without acceleration.

Suitable Moulding Methods Reduce Casting Costs. (*Giesserei*, 1954, **41,** Jan. 7, 23–24). The manufacture of an impeller is used as an example to compare the use of a wooden pattern with the core construction method. The partially completed mould, which is made up of numerous segments erected on a base, is illustrated. The essential advantages of this method are, first, that a better final finish can be obtained, avoiding the necessity of machining, venting between the blade walls is easy, and the blades are more uniform and of the same wall thickness.—R. J. W.

High Power Dielectric Heating for Industrial Use. W. H. Hickok. (*Indust. Heating*, 1954, **21,** Jan., 122–132). the growth of the method is reviewed. The heating equipment, in particular the oscillator generator and the applicator, are dealt with in detail. An overall efficiency of 60% has been obtained. One of its main applications is for baking foundry cores.—R. W. B.

Air Vents for Grey Castings. A. Schmitz. (*Giesserei*, 1954, **41,** Jan. 21, 51–52). The evolution of gases from moulds is considered and recommendations are made on the position of vents.—R. A. B.

Report of Castings Division, Investigation Committee of the Iron and Steel Institutte of Japan (I). K. Taniguchi. (*Tetsu to Hagane*, 1950, **36,** Aug., 362–364). [In Japanese]. Investigations reported include those on the composition, properties, and life of moulds, and on the hardnesses, depths of chill and compositions of various rolls.—K. E. J.

Long Centrifugal Castings. (*Engineer*, 1954, **197,** Apr. 16, 583). A brief description is given of a new casting technique developed by The United States Pipe and Foundry Co. which permits the molten metal to flow in a controlled manner from one end of the rotating metal mould to the other. The method is adopted in England by Sheepbridge Engineering Ltd.—M. D. J. B.

Precision Casting. W. Sulzer. (*Metall*, 1954, **8,** Feb., 115–116). The lost-wax method of precision casting is described, with plastics as the material for the patterns.—J. G. W.

Synthetic Resins and Their Use in the Foundry. J. J. Marais. (*Engineer Foundryman*, 1954, **18,** Jan., 70–74). The physical properties of urea-formaldehyde resins are discussed and the advantages of di-electric baking are stressed. Shell moulding is briefly mentioned. The technique of using vinyl resins for mould and pattern materials is explained. Other pattern materials described are polyester resins, PF resin, and plaster-resin-impregnated materials. The use of

a crystalline polystyrene for investment casting patterns is mentioned.—A. D. H.

HEATING FURNACES AND SOAKING PITS

Fuel Selection for Soaking Pits. F. R. Pullen. (*Iron Steel Eng.*, 1954, **31**, Mar., 80–82). A brief description is given of the modernization of soaking pits at the Bethlehem Steel Co., using fuel of low calorific valve and highly preheated air to step up performance.—M. D. J. B.

Speed, Control and Uniformity in Soaking Pit Heating. P. F. Kinyoun. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1953, 63–73: *Indust. Heating*, 1954, **21**, Apr., 706–708, 713–718, 830–834). The author discusses some of the factors which affect the speed and uniformity of soaking-pit heating, including pit design, ingot track-time, type and size of ingot, and method of firing. The use of automatic control for reversal, temperature, combustion air, pit pressure, fuel flow and fuel calorific value, is also considered, and the close interrelationship of speed, uniformity, and control of heating is emphasized.—G. F.

Automatically Controlled Ingot Soaking Pits in Operation at Inland Steel Company. (*Indust. Heating*, 1954, **21**, Jan., 38–42, 73–76). Details of construction and of the fully automatic control system are given for six surface combustion pits which held 8–11 ton ingots. The burners incorporate four 3 in. dia. pipes for coke-oven gas and one central $\frac{3}{4}$ in. dia. pipe for oil firing. With track times of 2–2$\frac{1}{2}$ hr. and heating times of 5 hr., fuel consumption is 17·8 therms /ton. A waste heat boiler recovers about 8·6 therms/ton.—R. W. B.

John Summers & Sons Limited—Soaking Pits. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 75–76). A very brief account of the ingot heating plant at John Summers & Sons Ltd. is given. It consists of 17 soaking-pits of three different types.—G. F.

A Layman's Comparison of Methods for Rapid Heating of Larger Steel Sections. H. E. Trout, jun. (*Steel Processing*, 1954, **40**, Feb., 111–114). The use of high intensity gas burners and electrical induction methods for rapid heating of billet material is very briefly outlined. Seven-inch square stock can be raised to 1200° C. in 30 min. by gas heating, and 13-in. square in 50 min. by 60-cycle induction.—P. M. C.

Studies on the Thermal Efficiency of the Reheating Furnaces. M. Shidera and K. Okada. (*Tetsu to Hagane*, 1951, **37**, Aug., 450–456). [In Japanese]. Works studies showed that the heat consumption in a wire rod mill could be reduced from approx. 800 to 500 $\times$ 10^3 kg. cal./ton of billets.—K. E. J.

Induction Heating in Modern Forging Plants. A. R. Baffrey. (International Mechanical Engineering Congress : *Metal Treatment and Drop Forg.*, 1954, **21**, Jan., 35–39). The effect of heating current frequency on power consumption in induction heating is discussed, and the normally used ranges are shown diagrammatically for material diameters up to 12 in. Other charts relate frequency, bar diameter, and heating times for both longitudinal and transverse charges. Information on, and illustrations of some Belgian heating units (by the Ateliers de Constructions Electriques de Charleroi) are given.—P. M. C.

Burners for Rolling-Mill Furnaces. Szczeniowski. (*Centre Doc. Sid., Circ. Inform. Tech.*, 1953, (9), 1453–1463). An outline is given of the factors involved in the assessment and modification of burners to achieve maximum efficiency and production. The functions of burners are considered and different burner designs such as the simple orifice, Siemens, ' Wärmestelle ', and Meyerhoffer burners are discussed.—A. G.

Recommendations for Minimizing Explosion Hazards in Ovens and Furnaces from Over Rich Combustion. J. B. Smith and E. H. Jones. (*Indust. Heating*, 1953, **20**, Oct., 1938–1966). Explosive mixtures which can result from poor adjustment of the burner mixture and the damper are discussed. With manufactured gas of 530 B.T.U./cu. ft. it is necessary to have at least 8·8% combustibles in the flue gas and 5·5% oxygen to produce an explosive mixture. Tests are described showing the effect of firing rate, aeration and recirculation rate on air infiltration.—R. W. B.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Application of Isothermal Heat-Treatment in the U.S.A. L. Rosseau. (*Metal Treatment and Drop Forg.*, 1954, **21**, Feb., 75–81). The three processes, austempering, isothermal annealing, and martempering are briefly described, the time-temperature relations in each case being illustrated with reference to a typical isothermal transformation diagram. The general preference for, and wide application of, salt baths are discussed, and their structural features both as heating and as quenching units are described. Some typical applications of each of the above processes are described, and the equipment is illustrated.—P. M. C.

British Developments in the Thermal Treatment of Metals and Alloys in Electric Furnaces. G. P. Tinker. (*Beama J.*, 1954, **61**, Mar., 71–77 ; Apr., 106–111). The author discusses the applicability of electric furnaces in ferrous and non-ferrous heat-treatment. Brief details are given of the type of electric furnace which are being increasingly used in the annealing, normalizing, tempering, and hardening of steel components. Horizontal batch, bogie hearth, pit-type, and continuous electric furnaces in general are referred to. The uses of resistor furnaces and immersed electrodes for salt baths, and the application of electric heating in salt bath descaling processes are indicated. Reference is also made to the rôle of electric heating in the annealing of iron castings.

Now Carbon Controller Makes Possible Accurate Carburizing, Carbon Restoration, Homogeneous Carburizing. W. L. Besselman. (*Mat. Methods*, 1954, **39**, Feb., 110–112). The Leeds and Northrup system for controlling the carbon potential of a heat-treating atmosphere is briefly outlined. An iron-alloy wire detecting element changes its electrical resistance if the carbon content of the atmosphere surrounding it changes. This phenomenon is used, through an electronic instrument, to regulate the flow of carburizing fluid to the furnace. The system is effective over a range from 0·15 to 1·15% C and a temperature range of 1450° to 1750° F. with an overall accuracy of measurement and control of $\pm$ 0·05% carbon.

New G.E.C. Oven. (*Wire Ind.*, 1954, **21**, Jan., 60). This is a vertical forced air circulation, conveyor oven for the heat-treatment of parts which are placed on twelve perforated swing trays. Automatic temperature control up to 250° C. and excess temperature cut-out are provided. The oven may be supplied for use with special atmospheres.—J. G. W.

Heat Treatment of Aircraft Parts. F. Crahen. (*Steel Processing*, 1954, **40**, Jan., 48, 49, 58). Methods and plant used for gas carburizing, clean hardening, and annealing of a great variety of small parts at the Jack and Heintz Co. Cleveland, U.S.A., are briefly described. All heat-treatment is carried out in batch type gas-fired and electric salt-bath furnaces.—P. M. C.

Modern Heat-Treat Department Enables Efficient Operation of Sheaffer's New Tool and Die Division. (*Indust. Heating*, 1954, **21**, Mar., 460–464). The installation, which includes three electric furnaces and an atmosphere generator, is described. The composition of the atmosphere generated is 40% hydrogen, 20% carbon monoxide, with the balance nitrogen. A protective flame curtain comes into operation when the doors are opened.—R. W. B.

A Study on the Heat-Treatment of Watch-Springs. T. Mishima, T. Mitsuhashi, and E. Asano. (*Tetsu to Hagane*, 1951, **37**, Aug., 457–460). [In Japanese]. Investigations were made concerning the effects of temperature on oxidation, decarburization, grain growth, oil quenching, and salt bath treatment.—K. E. J.

Bright Heating of Watch Spring Steel by Natural Gas. T. Mitsuhashi and K. Tsuya. (*J. Mech. Lab.*, 1953, **7**, Sept., 193–196). [In Japanese]. The use of a Mobara natural gas atmosphere for the bright annealing of 0·8%-carbon watch spring steel has been investigated.—J. G. W.

The Study for Heat Treatment in the Ball Bearing Steel (I). T. Mitsuhashi and M. Ueno. (*J. Mech. Lab.*, 1953, **7**, Nov., 209–222). [In Japanese]. Subzero treatment, oil quenching and tempering, martempering by oil cooling and by air cooling, were tried on the SUJ2 ball bearing steel. Some Charpy and compression tests were performed on annular specimens, and the dimensional stability of the retained austenite was studied with the following results : Best austenitizing temperature is 840° C. $\pm$ 5° C ; temper brittleness occurs at 180° C. and 250° C., but otherwise the oil quench and temper treatment is superior to the subzero treatment ; martempering gives very good properties except for low hardness.—J. G. W.

Calculation of Temperature Distribution in Wires in Patenting and Hardening Installations. W. Mallach. (*Draht, German ed.*, 1954, **5**, Mar., 83–89). Following a general

survey of heat-treatment installations for wire, elementary heat transfer theory is applied to the problem of design. It is shown that for optimum furnace utilization the strand speed should vary inversely with wire diameter and not, as is common practice, with the square of the diameter. A 10-ft. patenting furnace is described.—J. G. W.

Co-operation by Aircraft and Gas Engineers. (*Indust. Gas*, 1954, **17**, Apr., 204–214). The use of gas by certain firms, particularly the Engine Division of The Bristol Aircraft Co. Ltd. in the area of The South Western Gas Board is described. Brief mention is made of the gas installations in hardening shops, precision and non-ferrous foundries, and the blade forging department.—D. H.

Dew Point—A Means of Measuring the Carbon Potential of Prepared Atmospheres. N. K. Koebel. (*Metal Progress*, 1954, **65**, Feb., 90–96, 172). The use of dew-point measurements to control the gas composition required for heat-treating medium and high carbon tool steels which are obtained by cracking natural gas is discussed in detail. Details of the relationship between the dew point and the gas composition for carbon steels, low-alloy steels and tool steels are given.

Notes on the Relative Merits of Pack and Gas Carburizing. T. S. Lister. (*Machinery*, 1954, **84**, Apr. 30, 902–904). Gas carburizing has many advantages over the older method of pack carburizing, both technical and economic, but if these are to be fully exploited certain conditions must be fulfilled. Gas carburizing furnaces are unsuitable for hardening and refining, and skilled operators are required. This process requires laboratory facilities and expensive equipment.

A New Apparatus for Electric Spark Hardening of Tools. A. Plaskowski. (*Prace Instytutow Mechaniki*, 1953, **3**, (7), 70–71). [In Polish]. A description of the electric circuit of the apparatus is given.—V. G.

Cementation of Steel by Titanium in Molten Sodium Carbonate Containing Titanium Dioxide. S. Kowal. (*Prace Instytutow Mechaniki*, 1953, **3**, 6, 5–12). [In Polish]. The cementation of mild steel with titanium in a molten mixture of sodium carbonate and titanium dioxide in stoichiometric proportions was investigated. Prolonging the cementation time increases, and increase of temperature decreases the thickness of the cemented layer. The optimum temperature of the process is 880–890° C. The cemented layer consists of the solution of titanium in iron. The thickness of the cemented layer obtained was up to 65μ and its hardness in the hardened state about 690 Vickers and in the annealed state 270–280). In the presence of graphite (from the crucible) an intensive carbonization of steel takes place, particularly in the initial stage of the cementation process.—V. G.

Characteristics of Cemented Layer of Chromium Steel and Its Improvement by Heat-Treatment. T. Mishima and T. Mitsuhashi. (*Tetsu to Hagane*, 1951, **37**, Mar., 147–152). [In Japanese]. After cementation and oil-quenching, the surface layers of Ni–Cr steel are thinner, and the cores harder, than those of chromium steel. This may explain the flaking found with chromium steel ; annealing at 800–850° C. is recommended as a remedy.—K. E. J.

Calculation of the Flow of Gases from Circular Apertures (Jets) as Applied to the Practice of Gas-Flame Treatment of Metals. S. G. Guzov. (*Avtog. Delo*, 1953, (4), 12–15). [In Russian]. A simple formula is deduced for gas flow from circular orifices. The formula relates the channel and orifice dimensions, the gas pressure before the orifice, and the hourly discharge of gas. With the aid of tables for oxygen, air, nitrogen, hydrogen, methane, propane and acetylene, the formula can be used for rapid calculations of one of these parameters if the other two are known. No corrections for compressibility and viscosity over a considerable pressure range are required, except with hydrogen.—S. K.

FORGING, STAMPING, DRAWING, AND PRESSING

Modern Methods of Forging and Drop Forging. H. Hayes. (*Engineer Foundryman*, 1954, **18**, Jan., 53–59). The author describes the development of hammers and presses. The method of making drop stampings is outlined and the use of vertical forging presses and reducer rolls is reviewed.—A. D. H.

Manufacture and Properties of Large Forgings. A. O. Schaefer. (*Amer. Iron Steel Inst. Regional Technical Meetings*, 1953, 299–330 ; *Steel Processing*, 1954, **40**, Jan., 24–32, 59). The operations involved in making very large forgings are described and illustrated by a detailed account of the production of columns for the 25,000 ton press, ordered as part of the U.S.A. Air Force Heavy Press Programme. The columns, 43 in. in dia., 68 ft. long, weighing 142 short tons each as rough machined, were made in 2¼%-Ni–Cr–Mo steel. The ingots were 116 in. across the flats (12 sided), weighed 300 tons, and required the products of three open-hearth and one electric furnace each. The forging procedure under the 14,000-ton press and the elaborate 475-hr. heat treatment are described. As an example of a more complex shape, the production of a 35-ft. long shaft for a power station from a 220-ton carbon steel ingot is outlined. This had a variety of collars and barrel diameters and required eleven separate forging operations.—P. M. C.

A Comparison of American and German Drop Forging Practice. P. Hansen. (*Steel Processing*, 1954, **40**, Feb., 77–83). This is an English translation of a paper which appeared in *Stahl u. Eisen*, 1953, **73**, Nov. 5, 1473–1479. (*see J. Iron Steel Inst.*, 1954, **176**, Apr., 457).

Forging Procedures for Stainless Steels. L. F. Spencer. (*Indust. Heating*, 1953, **20**, Oct., 1916–1928 ; 1954, **21**, Jan., 44–46, 204–208). Forging and heating schedules are given for austenitic, martensitic and ferritic stainless steels, the maximum recommended temperatures being 2100°, 2000° and 1900° F. respectively. Particulars are given of a non-scaling steel (Armco 17-4PH with 16·5% Cr, 3·5% Ni and 3·5% Cu). Furnace and forging equipment are surveyed. Die life is 25% shorter than with plain carbon steels.—R. W. B.

Fork Trucks in a Drop Forge. (*Mech. Handling*, 1954, **41**, Apr., 209–210). Details are given of the use of fork trucks fitted with hydraulic manipulators in the forge department of the English Steel Corp., Sheffield. The trucks are mainly employed in the moving of material to and from the presses and reheating furnaces.—D. H.

Drop Forgings from the Customers Viewpoint. R. J. Brown. (National Assoc. Drop Forgers and Stampers : *Metal Treatment and Drop Forg.*, 1954, **21**, Feb., 51–55). The author's theme is that the development of competitive methods such as fabrication by welding or brazing, shell moulding, and extrusion, cannot be regarded with complacency by the drop-forging industry. The need to maintain a high standard and possibly to improve the quality of drop forgings is emphasized and discussed.—P. M. C.

Explosive Driven Bolts Made from Wire. K. Schimz. (*Draht, German ed.*, 1954, **5**, Feb., 53–54). Fasteners explosively driven into timber, brickwork, concrete, or steel, are made from wire. Methods of manufacture by machining, cold heading, and extrusion are described, and mention is made of the tests the fasteners are required to pass.—J. G. W.

Steam-Hydraulic *vs.* Hydraulic Forging Press. V. Tatarinov. (*Steel Processing*, 1953, **39**, Nov., 581). Data are given for dimensions and performance of two 600-ton presses for completing the forging of 5½-in. axles from 1210-lb. ingots. Calculated efficiencies show a 22% higher figure for the steam-hydraulic system.—P. M. C.

Universal Stretch Forming Tool. (*Metal Ind.*, 1954, **84**, Feb. 26, 163, 164 ; *Engineer*, 1954, **197**, Feb. 26, 324–325). A brief account, with illustrations and schematic diagrams, is given of a novel and simple tool capable of dealing with a variety of sizes and shapes of section which can be bent to any desired contour. The side members and base plate are steel channel sections, the rubbing plates are of compressed fibre, and the form block is wood. The actual stretching machine is a standard type. The technique which is simple, cheap, and flexible, was developed by Blackburn and General Aircraft Ltd.—P. M. C.

How to Choose Hydraulic Presses for Metal Forming Operations. H. D. Thweatt. (*Machinist*, 1954, **98**, May 1, 730–738). A survey of metal-working equipment in the U.S.A. showed that the number of hydraulic presses had increased by 21% between 1949 and 1953. The basic reasons for this increasing acceptance of presses for jobbing and production work are discussed.—M. A. K.

Elimination of 'Stretcher Strains' in Mild-Steel Pressings. B. B. Hundy. (*J. Iron Steel Inst.*, 1954, **178**, Oct., 127–138). [This issue].

Screw Press with Power-Assisted Control Gear. (*Engineering*, 1954, **177**, Apr. 2, 434–435). A description is given of a new 450-ton rated capacity press made by Taylor and Challen, Ltd., Birmingham. The press has a patented mechanical drive to the control gear.—M. D. J. B.

Die Life Is up 18 Times with Ductile Iron Dies. J. C. Neemes, jun. (*Machinist*, 1954, **98**, Mar. 27, 540–542). Heading, tapering, and bumper dies manufactured from heat-treated ductile iron and used in the manufacture of 20 mm. brass cartridge cases at the State Foundry and Machine Co. (U.S.A.), indicate additional possibilities for this new material.

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Problems in Rolling Mill Development. A. I. Zelikow. (*Engineering News*, Moscow, 1953, **6**, 20–25; *Met. u. Giesserei Techn.*, 1954, **4**, Apr., 164–168). The present status and some future problems for the improvement of rolling-mill machinery in the U.S.S.R are discussed.—R. A. R.

Titanium Carbide Rod Mill Guides Give Improved Rod Production. (*Iron Steel Eng.*, 1954, **31**, Mar., 121–122). The advantages of using titanium carbide for rod mill guides are described. It is claimed that guides of this material, which is especially adapted for handling red-hot rod, has a life of 1600 hr.—M. D. J. B.

The Diversity of Products of Low Individual Tonnages. W. J. McClung. (*Iron Steel Eng.*, 1954, **31**, Apr., 101–104). The author discusses briefly the problems involved in rolling small quantities of a wide variety of sizes, shapes, and grades as experienced by mills on the Pacific Coast of the U.S.A.

The Relation between Roll Pass Design and a Hair-Like Crack in Wire Rod. R. Yoshida. (*Tetsu to Hagane*, 1951, **37**, July, 427–430). [In Japanese]. The oval-round-oval and oval-oval series of passes are more successful than the oval-square-oval series for eliminating surface cracks.—K. E. J.

Continental Steel Corporation's New High-Speed Rod Mill. D. C. Horsman and A. Wilson. (*Wire and Wire Prod.*, 1954, **29**, Mar., 261–264, 342). The United Rendlemann Rod Mill recently put into operation at Kokomo, Indiana, is described in detail. It is a three-strand, 22-stand mill for rolling $2\frac{1}{4}$ in. square billets to $1\frac{1}{4}$–$\frac{7}{32}$-in. dia. rod at up to 5750 ft./min. There are no oval passes in the roughing train, and the rod is cropped before entering the finishing train.—J. G. W.

Relation between the Size of Caliber and Cracks of Small Rounds. R. Yoshida. (*Tetsu to Hagane*, 1951, **37**, Mar., 145–146). [In Japanese]. Some explanation is given for the formation of hairlike cracks and seams during rolling of small rounds (6–15 mm. in dia), particularly in special steels.

Rolls and Rolling. Part 37. Tie Plates. E. E. Brayshaw. (*Blast Furn. Steel Plant*, 1953, **41**, Nov., 1313–1321). The design of passes for the rolling of soleplates for fixing flat-bottomed rails to sleepers is discussed in detail. The design is characterized by uneven drafting which causes difficulties due to the production of a camber in the bar as it is rolled.

Steel Sheet Rolling and Annealing Practice. N. G. Fraser. (*Australian Inst. Metals, Australasian Eng.* 1954, Jan. 7, 65–74). After describing the various types of mill used in both hot and cold steel sheet rolling, (two, three, and four high, continuous, reversing, multi-stand) the author outlines the methods followed at the C.R.M. Division of Lysaghts Works Pty. Ltd., Port Kembla, N.S.W. Consideration is also given to the reasons for annealing sheets and the various types of furnace are described. At C.R.M., furnaces with portable covers fired with coke-oven gas are employed. Operating procedure is outlined.—P. M. C.

Electrical Steel—A Triumph of Steelmaking, Heat-Treatment and Scientific Metallurgy. W. Jones. (*Metal Progress*, 1954, **65**, Feb., 70–74). An historical survey is made of the development of iron-silicon alloys which have special magnetic properties and find wide application in transformer construction. The heating and rolling treatments used during manufacture and the production of very thin sheet are discussed.

Mechanized Sheet and Tinplates Mills—Electrical Energy Consumption. J. H. Mort. (*Iron Steel*, 1954, **27**, Jan., 3–7; Feb., 55–60; Mar., 83–87; Apr., 141–144). The author discusses the power requirements of mechanized sheet and tin plate mills, considering only the power transmitted by the main mill motors and excluding the energy expended on ancillary apparatus. A brief description of the different types of mill unit and their operation is first given, followed by an outline of the mathematics involved in deriving the formulæ for calculating energy requirements. Detailed examples are then given of their application to 3-high mills, 2-high finishing sheet mills, and 2-high finishing tinplate mills. Graphical solutions of the formulæ are illustrated.—G. F.

John Summers & Sons Limited—Slabbing Mill. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 76–78, 102). Details are given of the new 55-in. slabbing mill and slab shear installed at John Summers & Sons Ltd., and features of particular interest are discussed. The mill makes use of an existing steam engine drive, details of which are also given.

John Summers & Sons Limited—Continuous Hot Strip Mill. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 79–80). The complete hot mill installation at John Summers & Sons Ltd. Consists of the reheating furnaces, the mill, and the coiler. Details are given of each section, and the sequence of operations is outlined. The method of handling the finished hot-rolled coil is also described.—G. F.

John Summers & Sons Limited—Cold Reduction and Processing. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 81–88). In this article on the treatment of hot-rolled strip at John Summers & Sons Ltd., details are first given of the continuous pickling lines. General descriptions are then given of the design and operation of the 4-stand cold reduction mill and the 80-in. cold reduction reversing mill. The coil cut-up lines are next considered briefly, followed by details of the annealing process and furnaces. Finally, the operation of the three skin-pass mills is outlined.—G. F.

Electric Drive of a Reversing Cold Strip Mill for Rolling Stainless Steel. L. N. Butler. (*Metro. Vick. Gaz.*, 1953, **25**, Oct., 88–91). A description is given of the reversing mill installed by Firth-Vickers Stainless Steels Ltd. at the new Shepcote Lane Works, Sheffield. This four-high reversing mill was built by W. H. A. Robertson and Co. Ltd., Bedford. The work rolls are 17 in. and the back-up rolls 49 in. in dia., the roll faces being 50 in. wide, and the mill is designed for rolling speeds of 0/400/800 ft. p.m. Metadynes are used for tension regulation and speed synchronizing.—L. E. W.

Electrical Drive for a Planetary Rolling Mill. (*Engineer*, 1954, **197,** Mar. 26, 458–459). This article describes particulars of the electrical equipment, which was supplied by the English Electric Co., Ltd. for the main and auxiliary drives of a hot strip rolling mill at the works of Ductile Planetary Mills Ltd.—M. D. J. B.

Unusual Electric Drive Features Applied to Fairless Processing Lines. E. E. Vonada. (Amer. Inst. Elec. Eng. : *Iron Steel Eng.*, 1954, **31,** Apr., 114–119). The author describes the sequence of the mechanical units in the processing line of the wide strip mills at the Fairless Works of the United States Steel Corp., and the generating and booster system employed to apply adjustable voltage power to some of the driving motors.—M. D. J. B.

A New Technique for Investigating Surface Flow in Metal Working Processes. J. M. Capus and M. G. Cockcroft. (*Nature*, 1954, **173,** May, 821). When a metal strip undergoes reduction between rolls it is accelerated and its relative movement results in scratches due to adventitious projections on the roll surfaces. These scratches enable surface flow to be investigated and a preliminary study shows that homogeneous deformation may be assumed and that the frictional force is by no means parallel to the rolling direction.—A. G.

The Influence of Roll Dimensions in Cold Rolling of Thin Metal Sheets and Strip. A. Geleji. (*Acta Techn.*, 1953, **7,** (1–2), 217–233). [In German]. The resistance to rolling decreases with decrease in the diameter of the work rolls. The degree of roll flattening depends on the rolling pressure. Resistance to working increases with arc of contact. Roll flattening and the arc of contact can be calculated using the formula for the resistance to deformation and the Herz formula for the flattening of rolls pressed together. The derived formulæ give satisfactory practical data.—R. P.

LUBRICANTS AND LUBRICATION

The Stribeck Curve as Index of General Frictional Behaviour of Lubricated Sliding Surfaces. G. Vogelpohl. (*Z. V. d. I.*, 1954, **96,** Mar. 21, 261–268). Having outlined the principles of the hydrodynamic theory of thick film lubrication, the author supports Stanton's observation that some hydrodynamic action exists right from the initiation of motion and criticises the 'boundary layer' approach of recent English and American workers. He shows qualitatively how the law of the 'mixed regime' of thin-film lubrication can be established with the aid of hydrodynamic concepts. (26 references).—J. G. W.

Reclamation of Used Lubricating Oil. T. T. N. Coleridge. (*New Zealand Eng.*, 1953, **8,** June, 196–201). A detailed account is presented of the methods, aims, and potentialities of lubricating oil reclamation and purification. Oils with and without additives are discussed, and the nature and consequences of the impurities and deterioration caused by different types of service are dealt with.—P. M. C.

WELDING AND FLAME-CUTTING

Powered Iron Invades Electrode Design. L. K. Stringham. (*Iron Steel Eng.*, 1954, **31,** Mar., 127–128). This article describes heavily coated welding electrodes containing large quantities of powdered metal in their coatings which, it is claimed, give increased welding speeds and better appearance.

Electrode Material for Resistance Welding. W. J. Armstrong and H. D. Baer. (*Welding Metal Fab.*, 1954, **22,** Mar. 95–97). The requirements and selection of suitable electrode materials for resistance welding are discussed.—U. E.

Tentative Code of International Symbols for Designating Covered Electrodes for Arc Welding of Mild and Low-Alloy High-Tensile Steels. (*Brit. Welding, J.* 1954, **1,** May, 205–208).

Multitransformer Welding Processes. J. Ogden. (*Trans. Amer. Inst. Elec. Eng.*, 1953, **72,** Part II, 202–208).

An Apparatus for Protection Against Dangerous Voltages in Welding Equipment. F. H. de Jong and R. W. van Rheenen. (*Philips Tech. Rev.*, 1954, **15,** Jan., 199–204).

Hydrogen—Barrier to Welding Progress. C. L. M. Cottrell. (*Brit. Welding J.*, 1954, **1,** Apr., 167–176). The paper deals with the adverse effect of hydrogen in the welding of steels. The sources of hydrogen, and the effect of hydrogen on the mechanical properties of the steel are discussed. A new method of assessing weldability of a steel in terms of a measurable physical property of the material is considered.—U. E.

The Electric Arc in Argon and Helium. T. B. Jones, M. Skolnik, and W. B. Kouwenhoven. (*Trans. Amer. Inst. Elec. Eng.*, 1953, **72,** Part II, 16–21). This paper presents the electrical characteristics of the D.C. tungsten arc for the current range of 10–100 amp. in an argon atmosphere and describes the qualitative behaviour of this arc. Data for the tungsten arc in helium are also given.—R. A. R.

The Determination of Droplet Size in Arc Welding by High-Speed Cinematography. P. C. Van der Willigen and L. F. Defize. (*Philips Tech. Rev.*, 1953, **15,** Oct., 122–128). A technique is described and illustrated for filming, at a picture frequency of up to 3000/sec., the size of the droplets of weld metal transferred from welding electrodes to the work. Some of the measurements made using various types of Philips electrodes are discussed with reference to electrode diameter, composition of rod and coating, and electrical characteristics. Colour films have also been made and are reproduced. (11 references).—P. M. C.

Microcracks in Weld Metal. P. C. Van der Willigen. (*J. Sci. Indust. Res.*, 1954, **13,** Jan., 26–20). An investigation of temperature-change effects on weld metal has shown that microcracks are formed most easily when the electrodes produce much hydrogen, and when heavy or cold plates are welded, *i.e.*, when the weld cools rapidly between 200° and 150° C.—J. O. L.

Influence of Hydrogen and Silicon in Arc Welding. J. L. Zuloaga. (*Cien. Tecn. Solda*, 1953, **111,** Nov.-Dec.). [In Spanish]. A description is given of the effect of hydrogen on the properties of welded joints and the influence of the presence of more or less silicon on the effect of the hydrogen. The solubility of hydrogen in steel and methods for its determination are indicated. An apparatus for determining hydrogen by vacuum extraction is described and drawn.

Pressure Welding Experiments with Armco Iron at Temperatures Between 400 and 800°. H. Held and H. Hendus. (*Z. Metallkunde*, 1954, **45,** Mar., 112–116). Welding tests were carried out *in vacuo* on Armco iron test pieces with plane surfaces with a given load at 400–800° C. It was found possible to account for the strength of the weld seam by its hardness, without taking into account diffusion or other processes.

Some Oxidation Effects during the Pressure Welding of Steels. J. E. Hughes. (*Brit. Welding J.*, 1954, **1,** Apr., 161–166). The part played by internal oxidation in pressure welds made by commercial techniques is discussed. It has been demonstrated that insoluble inclusions at the weld plane, and not submicroscopic voids as previously postulated, constitute the probable cause of low notch-impact strength under certain conditions.—U. E.

Weldability of Mn–Mo Steel Related to Properties of the Heat-Affected Zone. C. L. M. Cottrell. (*Brit. Welding J.*, 1954, **1,** Apr., 177–186). The mechanical properties of a commercial Mn–Mo steel have been studied after simulating the conditions which occur in the heat-affected zone adjacent to metal-arc welds. Various cooling rates have been used to cover the range which occurs in normal metal arc welding. Best correlation between mechanical test results and weldability (liability to cold cracking in the heat-affected zone) was obtained using the dead-load tensile test. A mechanism for the initiation of these cracks is suggested.—U. E.

Effect of Surface Conditions on Porosity and Mechanical Properties of Weld Metal. K. Winterton. (*Welding Metal Fab.*, 1954, **22,** Mar., 101–104). Using six electrodes to represent various types from the B.S. 1719 classification, tests were carried out to examine the effect of various conditions of the plate surface on weldability, as indicated by porosity and mechanical properties. The effect of light machine oil, gas-cut edges, rust and scale were investigated. The general effects were small except in the case of mill scale, which increased the porosity and reduced the tensile strength of the plate.—U. E.

Shielded Arc Welding. (*Automobile Eng.*, 1954, **44,** Mar., 108–110). Recent American developments are reviewed, and descriptions are given of the Heliarc process—in which the arc is maintained between a single tungsten electrode and the base metal, and blanketed by argon gas ; the Sigma process—which uses a consumable wire electrode, also fed through argon gas ; and the Unionmelt process—which also uses a consumable wire electrode but in which the shielding agent is a granular flux which pours down over the weld.

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Titanium Carbide Rod Mill Guides Give Improved Rod Production. (*Iron Steel Eng.*, 1954, **31**, Mar., 121–122). The advantages of using titanium carbide for rod mill guides are described. It is claimed that guides of this material, which is especially adapted for handling red-hot rod, has a life of 1600 hr.—M. D. J. B.

The Diversity of Products of Low Individual Tonnages. W. J. McClung. (*Iron Steel Eng.*, 1954, **31**, Apr., 101–104). The author discusses briefly the problems involved in rolling small quantities of a wide variety of sizes, shapes, and grades as experienced by mills on the Pacific Coast of the U.S.A.

The Relation between Roll Pass Design and a Hair-Like Crack in Wire Rod. R. Yoshida. (*Tetsu to Hagane*, 1951, **37**, July, 427–430). [In Japanese]. The oval-round-oval and oval-oval series of passes are more successful than the oval-square-oval series for eliminating surface cracks.—K. E. J.

Continental Steel Corporation's New High-Speed Rod Mill. D. C. Horsman and A. Wilson. (*Wire and Wire Prod.*, 1954, **29**, Mar., 261–264, 342). The United Rendlemann Rod Mill recently put into operation at Kokomo, Indiana, is described in detail. It is a three-strand, 22-stand mill for rolling $2\frac{1}{2}$ in. square billets to $1\frac{1}{4}-\frac{7}{32}$-in. dia. rod at up to 5750 ft./min. There are no oval passes in the roughing train, and the rod is cropped before entering the finishing train.—J. G. W.

Relation between the Size of Caliber and Cracks of Small Rounds. R. Yoshida. (*Tetsu to Hagane*, 1951, **37**, Mar., 145–146). [In Japanese]. Some explanation is given for the formation of hairlike cracks and seams during rolling of small rounds (6–15 mm. in dia), particularly in special steels.

Rolls and Rolling. Part 37. Tie Plates. E. E. Brayshaw. (*Blast Furn. Steel Plant*, 1953, **41**, Nov., 1313–1321). The design of passes for the rolling of soleplates for fixing flat-bottomed rails to sleepers is discussed in detail. The design is characterized by uneven drafting which causes difficulties due to the production of a camber in the bar as it is rolled.

Steel Sheet Rolling and Annealing Practice. N. G. Fraser. (*Australian Inst. Metals, Australasian Eng.* 1954, Jan. 7, 65–74). After describing the various types of mill used in both hot and cold steel sheet rolling, (two, three, and four high, continuous, reversing, multi-stand) the author outlines the methods followed at the C.R.M. Division of Lysaghts Works Pty. Ltd., Port Kembla, N.S.W. Consideration is also given to the reasons for annealing sheets and the various types of furnace are described. At C.R.M., furnaces with portable covers fired with coke-oven gas are employed. Operating procedure is outlined.—P. M. C.

Electrical Steel—A Triumph of Steelmaking, Heat-Treatment and Scientific Metallurgy. W. Jones. (*Metal Progress*, 1954, **65**, Feb., 70–74). An historical survey is made of the development of iron-silicon alloys which have special magnetic properties and find wide application in transformer construction. The heating and rolling treatments used during manufacture and the production of very thin sheet are discussed.

Mechanized Sheet and Tinplates Mills—Electrical Energy Consumption. J. H. Mort. (*Iron Steel*, 1954, **27**, Jan., 3–7 ; Feb., 55–60 ; Mar., 83–87 ; Apr., 141–144). The author discusses the power requirements of mechanized sheet and tin plate mills, considering only the power transmitted by the main mill motors and excluding the energy expended on ancillary apparatus. A brief description of the different types of mill unit and their operation is first given, followed by an outline of the mathematics involved in deriving the formulæ for calculating energy requirements. Detailed examples are then given of their application to 3-high mills, 2-high finishing sheet mills, and 2-high finishing tinplate mills. Graphical solutions of the formulæ are illustrated.—G. F.

John Summers & Sons Limited—Slabbing Mill. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 76–78, 102). Details are given of the new 55-in. slabbing mill and slab shear installed at John Summers & Sons Ltd., and features of particular interest are discussed. The mill makes use of an existing steam engine drive, details of which are also given.

John Summers & Sons Limited—Continuous Hot Strip Mill. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 79–80). The complete hot mill installation at John Summers & Sons Ltd. Consists of the reheating furnaces, the mill, and the coiler. Details are given of each section, and the sequence of operations is outlined. The method of handling the finished hot-rolled coil is also described.—G. F.

John Summers & Sons Limited—Cold Reduction and Processing. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 81–88). In this article on the treatment of hot-rolled strip at John Summers & Sons Ltd., details are first given of the continuous pickling lines. General descriptions are then given of the design and operation of the 4-stand cold reduction mill and the 80-in. cold reduction reversing mill. The coil cut-up lines are next considered briefly, followed by details of the annealing process and furnaces. Finally, the operation of the three skin-pass mills is outlined.—G. F.

Electric Drive of a Reversing Cold Strip Mill for Rolling Stainless Steel. L. N. Butler. (*Metro. Vick. Gaz.*, 1953, **25**, Oct., 88–91). A description is given of the reversing mill installed by Firth-Vickers Stainless Steels Ltd. at the new Shepcote Lane Works, Sheffield. This four-high reversing mill was built by W. H. A. Robertson and Co. Ltd., Bedford. The work rolls are 17 in. and the back-up rolls 49 in. in dia., the roll faces being 50 in. wide, and the mill is designed for rolling speeds of 0/400/800 ft. p.m. Metadynes are used for tension regulation and speed synchronizing.—L. E. W.

Electrical Drive for a Planetary Rolling Mill. (*Engineer*, 1954, **197,** Mar. 26, 458–459). This article describes particulars of the electrical equipment, which was supplied by the English Electric Co., Ltd. for the main and auxiliary drives of a hot strip rolling mill at the works of Ductile Planetary Mills Ltd.—M. D. J. B.

Unusual Electric Drive Features Applied to Fairless Processing Lines. E. E. Vonada. (Amer. Inst. Elec. Eng. : *Iron Steel Eng.*, 1954, **31,** Apr., 114–119). The author describes the sequence of the mechanical units in the processing line of the wide strip mills at the Fairless Works of the United States Steel Corp., and the generating and booster system employed to apply adjustable voltage power to some of the driving motors.—M. D. J. B.

A New Technique for Investigating Surface Flow in Metal Working Processes. J. M. Capus and M. G. Cockcroft. (*Nature*, 1954, **173,** May, 821). When a metal strip undergoes reduction between rolls it is accelerated and its relative movement results in scratches due to adventitious projections on the roll surfaces. These scratches enable surface flow to be investigated and a preliminary study shows that homogeneous deformation may be assumed and that the frictional force is by no means parallel to the rolling direction.—A. G.

The Influence of Roll Dimensions in Cold Rolling of Thin Metal Sheets and Strip. A. Geleji. (*Acta Techn.*, 1953, **7,** (1–2), 217–233). [In German]. The resistance to rolling decreases with decrease in the diameter of the work rolls. The degree of roll flattening depends on the rolling pressure. Resistance to working increases with arc of contact. Roll flattening and the arc of contact can be calculated using the formula for the resistance to deformation and the Herz formula for the flattening of rolls pressed together. The derived formulæ give satisfactory practical data.—R. P.

LUBRICANTS AND LUBRICATION

The Stribeck Curve as Index of General Frictional Behaviour of Lubricated Sliding Surfaces. G. Vogelpohl. (*Z. V. d. I.*, 1954, **96,** Mar. 21, 261–268). Having outlined the principles of the hydrodynamic theory of thick film lubrication, the author supports Stanton's observation that some hydrodynamic action exists right from the initiation of motion and criticises the 'boundary layer' approach of recent English and American workers. He shows qualitatively how the law of the 'mixed regime' of thin-film lubrication can be established with the aid of hydrodynamic concepts. (26 references).—J. G. W.

Reclamation of Used Lubricating Oil. T. T. N. Coleridge. (*New Zealand Eng.*, 1953, **8,** June, 196–201). A detailed account is presented of the methods, aims, and potentialities of lubricating oil reclamation and purification. Oils with and without additives are discussed, and the nature and consequences of the impurities and deterioration caused by different types of service are dealt with.—P. M. C.

WELDING AND FLAME-CUTTING

Powered Iron Invades Electrode Design. L. K. Stringham. (*Iron Steel Eng.*, 1954, **31,** Mar., 127–128). This article describes heavily coated welding electrodes containing large quantities of powdered metal in their coatings which, it is claimed, give increased welding speeds and better appearance.

Electrode Material for Resistance Welding. W. J. Armstrong and H. D. Baer. (*Welding Metal Fab.*, 1954, **22,** Mar. 95–97). The requirements and selection of suitable electrode materials for resistance welding are discussed.—U. E.

Tentative Code of International Symbols for Designating Covered Electrodes for Arc Welding of Mild and Low-Alloy High-Tensile Steels. (*Brit. Welding, J.* 1954, **1,** May, 205–208).

Multitransformer Welding Processes. J. Ogden. (*Trans. Amer. Inst. Elec. Eng.*, 1953, **72,** Part II, 202–208).

An Apparatus for Protection Against Dangerous Voltages in Welding Equipment. F. H. de Jong and R. W. van Rheenen. (*Philips Tech. Rev.*, 1954, **15,** Jan., 199–204).

Hydrogen—Barrier to Welding Progress. C. L. M. Cottrell. (*Brit. Welding J.*, 1954, **1,** Apr., 167–176). The paper deals with the adverse effect of hydrogen in the welding of steels. The sources of hydrogen, and the effect of hydrogen on the mechanical properties of the steel are discussed. A new method of assessing weldability of a steel in terms of a measurable physical property of the material is considered.—U. E.

The Electric Arc in Argon and Helium. T. B. Jones, M. Skolnik, and W. B. Kouwenhoven. (*Trans. Amer. Inst. Elec. Eng.*, 1953, **72,** Part II, 16–21). This paper presents the electrical characteristics of the D.C. tungsten arc for the current range of 10–100 amp. in an argon atmosphere and describes the qualitative behaviour of this arc. Data for the tungsten arc in helium are also given.—R. A. R.

The Determination of Droplet Size in Arc Welding by High-Speed Cinematography. P. C. Van der Willigen and L. F. Defize. (*Philips Tech. Rev.*, 1953, **15,** Oct., 122–128). A technique is described and illustrated for filming, at a picture frequency of up to 3000/sec., the size of the droplets of weld metal transferred from welding electrodes to the work. Some of the measurements made using various types of Philips electrodes are discussed with reference to electrode diameter, composition of rod and coating, and electrical characteristics. Colour films have also been made and are reproduced. (11 references).—P. M. C.

Microcracks in Weld Metal. P. C. Van der Willigen. (*J. Sci. Indust. Res.*, 1954, **13,** Jan., 26–20). An investigation of temperature-change effects on weld metal has shown that microcracks are formed most easily when the electrodes produce much hydrogen, and when heavy or cold plates are welded, *i.e.*, when the weld cools rapidly between 200° and 150° C.—J. O. L.

Influence of Hydrogen and Silicon in Arc Welding. J. L. Zuloaga. (*Cien. Tecn. Solda*, 1953, **111,** Nov.-Dec.). [In Spanish]. A description is given of the effect of hydrogen on the properties of welded joints and the influence of the presence of more or less silicon on the effect of the hydrogen. The solubility of hydrogen in steel and methods for its determination are indicated. An apparatus for determining hydrogen by vacuum extraction is described and drawn.

Pressure Welding Experiments with Armco Iron at Temperatures Between 400 and 800°. H. Held and H. Hendus. (*Z. Metallkunde*, 1954, **45,** Mar., 112–116). Welding tests were carried out *in vacuo* on Armco iron test pieces with plane surfaces with a given load at 400–800° C. It was found possible to account for the strength of the weld seam by its hardness, without taking into account diffusion or other processes.

Some Oxidation Effects during the Pressure Welding of Steels. J. E. Hughes. (*Brit. Welding J.*, 1954, **1,** Apr., 161–166). The part played by internal oxidation in pressure welds made by commercial techniques is discussed. It has been demonstrated that insoluble inclusions at the weld plane, and not submicroscopic voids as previously postulated, constitute the probable cause of low notch-impact strength under certain conditions.—U. E.

Weldability of Mn–Mo Steel Related to Properties of the Heat-Affected Zone. C. L. M. Cottrell. (*Brit. Welding J.*, 1954, **1,** Apr., 177–186). The mechanical properties of a commercial Mn–Mo steel have been studied after simulating the conditions which occur in the heat-affected zone adjacent to metal-arc welds. Various cooling rates have been used to cover the range which occurs in normal metal arc welding. Best correlation between mechanical test results and weldability (liability to cold cracking in the heat-affected zone) was obtained using the dead-load tensile test. A mechanism for the initiation of these cracks is suggested.—U. E.

Effect of Surface Conditions on Porosity and Mechanical Properties of Weld Metal. K. Winterton. (*Welding Metal Fab.*, 1954, **22,** Mar., 101–104). Using six electrodes to represent various types from the B.S. 1719 classification, tests were carried out to examine the effect of various conditions of the plate surface on weldability, as indicated by porosity and mechanical properties. The effect of light machine oil, gas-cut edges, rust and scale were investigated. The general effects were small except in the case of mill scale, which increased the porosity and reduced the tensile strength of the plate.—U. E.

Shielded Arc Welding. (*Automobile Eng.*, 1954, **44,** Mar., 108–110). Recent American developments are reviewed, and descriptions are given of the Heliarc process—in which the arc is maintained between a single tungsten electrode and the base metal, and blanketed by argon gas ; the Sigma process—which uses a consumable wire electrode, also fed through argon gas ; and the Unionmelt process—which also uses a consumable wire electrode but in which the shielding agent is a granular flux which pours down over the weld.

These processes are remarkable for the weld finish and cleanliness, speed (200 in./min. has been obtained on $\frac{1}{16}$ in. material), and automatic applications.—P. M. C.

New Developments in Sigma Welding of Carbon Steels. T. McElrath and R. T. Telford. (*Canad. Metals*, 1954, **17,** Jan., 38–41 ; Feb., 34–38). **Look for More Sigma Welding of Carbon Steels.** T. McElrath and R. T. Telford. (*Steel*, 1954, **134,** Feb. 22, 104–106). The use of the shielded inert-gas metal-arc welding technique for carbon steels is discussed in detail. Porosity in carbon steel weld metal has been overcome by the development of a new type of welding wire. A mixture of 5% oxygen in argon is the gas used.—B. G. B.

A Progress Report on Shielded-Tungsten Arc Welding. H. A. Huff, and A. N. Kugler. (*Product. Eng*, 1954, **25,** Feb., 170–174). The Heliweld welding technique is being stimulated by expansion in the use of stainless steel and other thin gauge materials. Types of equipment, the importance of precision jigs and fixtures, the differences between helium and argon as shielding gases, and joint designs are described. Amongst the materials weldable by this process are, carbon and stainless steels, high temperature alloys, nickel alloys, and cast iron.—A. M. F.

The Modern Electric Weld Pipe and Casing Mill. N. C. Rubin. (*Iron Steel Eng.*, 1954, **31,** Apr., 120–123). The author describes the new large electric resistance weld pipe mills recently installed at the Lone Star Steel Co. The smaller mill produces pipes from 2 to 6⅝ in. in outside dia. with wall thicknesses from 0·125 in. to 0·337 in. The larger mill has a capacity from 4½ to 16 in. in outside dia. with wall thicknesses from 0·125 in. to 0·557 in. The max. speeds are 150 ft./min. for the smaller mill and 120 ft./min. for the larger.—M. D. J. B.

Control for a Modern Electric Weld Pipe and Casing Mill. C. E. Smith. (*Iron Steel Eng.*, 1954, **31,** Apr., 124–130). The author describes the electrical controls furnished for a large resistance welding tube mill installed at the Lone Star Steel Co. in Texas. The greater part of the paper concerns only the controllers for the adjustable voltage D.C. drives and the power source for welding.—M. D. J. B.

Metallurgical Aspects of Chain Manufacture. J. Waring. (*Australasian Eng.*, 1953, Nov. 7, 52–58). The author reviews most of the more commonly used methods of steel chain manufacture and the metallurgical problems encountered therein. Most of the paper is devoted to short-link pitched and calibrated chain and stud-link chains to B.S. 590 (1949), B.S. 1663 (1950), and B.S. 3006 (1949). The two main methods for the production of the former (resistance and flash butt welding), and the three main methods for production of the latter (casting, drop forging by the U.S. Di-Lok process, and electric welding) are discussed. A short review is also given of the making of roller and conveyor chain.—P. M. C.

Distortion Can Be Designed out of Welded Structures. J. R. Stitt. (*Steel*, 1954, **134,** Mar. 8, 120–122). The distorting effect of welding or heat on metal members and structures is described. Examples of ways of minimizing the effect are given, with an example of recovery, by flame straightening.

Deformation and Stresses in the Concentrated Local Heating of Steel Sheet. O. A. Bakshi. (*Avtog. Delo*, 1953, (2), 1–6). [In Russian]. The object of the investigation reported was the theoretical solution, based on a combination of the modern theory of plasticity with Okerblom's theory of welding stresses and deformation, of the problem of deformation and stress during local and intense heating of steel sheet, as occurs in welding. The solution obtained is based on elastic-plastic equilibrium in thin circular discs heated symmetrically to the axis and enables deformation and stress to be found for thin sheets of any shape if their planar dimensions exceed by a factor of 3–4 those of the 600° C. temperature zone. Both temporary and residual stresses can be found for spot welding, electric riveting, and similar processes.—S. K.

The Welding of Nickel Alloy Steels. (*Steel Processing*, 1953, **39,** Nov., 573–580, 611 ; 1954, **40,** Jan., 39–47, 53). In this paper nickel alloy steels are grouped arbitrarily into four general classifications with respect to weldability : (1) The high-strength low-alloy constructional steels, (2) the low carbon, (3) medium carbon, and (4) high carbon and special types. Metal arc welding is dealt with in Part I, and Part II deals with electrodes for metal arc welding and other welding methods. (20 references).—P. M. C.

Welding Problems in the Construction of a Modern Boiler Plant. F. L. Dingle. (*Australasian Eng.*, 1953, Nov. 7, 46–51). The boiler and high temperature steam plant at the new Pyrmont "B" Power Station, New South Wales, is described, and full details of the welding problems, procedures, joint designs, and testing and inspection methods are given.

Induction Welding, Particularly of Tube Seams, and Its Application. E. Hörmann. (*Z.V.d.I.*, 1954, **96,** Jan. 21, 65–72). Following a general description of the process, the author discusses and illustrates weld structure pressure, temperature distribution, the relation between pressure and temperature, induction coil and fixture design, and plant for the manufacture of induction-welded pipes.—J. G. W.

Electric Welding of Cast Iron with Cast-Iron Electrodes without Preheating, Using a Granulated Mixture. A. I. Zelenov. (*Avtog. Delo*, 1953, (4), 7–9). [In Russian]. Small scale and industrial scale experiments are described in which cast iron was electric welded with various types of electrodes without preheating. The welds were subjected to mechanical testing and microscopical investigations, leading to the following conclusions : With chalk-covered cast-iron electrodes and a 4–6 mm. layer of granulated flux, the properties of the deposited and base metals were very similar, and a readily machinable structure resulted ; the method recommended can be used with both A.C. and D.C. and has a higher productivity than present methods. Examples of welding repairs by this technique are cited.—S. K.

Apparatus PMR-600 for the Oxygen-Cutting of Steel up to 600 mm. Thick. (*Stanki i Instrument*, 1953, (11), 38). [In Russian]. Details are given of a new oxygen-cutting machine for use in the heavy machine industry and in a variety of metallurgical applications.—S. K.

Development and Applications of Flame-Cutting with Entrained Powder. B. Trzeciak. (*Met. u. Giesserei Techn.*, 1954, **4,** Apr., 179–182). The physical and chemical principles of cutting cast iron and alloy steel and the more usual methods of cutting are discussed. The author prefers the thermal process, in which iron powder is added to the flame by compressed air. He describes modifications to the powder and the apparatus.—L. J. L.

Modern Flame-Cutting Equipment: A Review of Recent Developments in German Designs. R. Bechtle. (*Iron Coal Trades Rev.*, 1954, **168,** Apr. 9, 845–853). The author discusses the relative values of gases used in flame-cutting processes, giving information on the desirable properties of the steel for successful cutting, and on the quality of the resulting surface. Modern examples of German cutting equipment are described, and the accuracy and efficiency of the various techniques are compared.—G. F.

Use of Oxyacetylene in Rolling Mills. R. L. Deily. (*Iron Steel Eng.*, 1954, **31,** Mar., 83–90). The numerous uses of oxyacetylene in rolling mill operation are described. Scarfing installations, the hot-cutting process, technical data, and machinery are discussed.—M. D. J. B.

MACHINING AND MACHINABILITY

A Numbering System for Carbide Tipped Tools. G. Bennett. (*Australian Machinery*, 1954, **7,** Jan., 4–10). In order to simplify stocking, to encourage the use of standard tools, and to reduce design and drawing time to a minimum, a numbering system has been devised and is operating successfully in a large Australian machine shop. The style, shank size, type of tip, and details of tip angles are all indicated by a series of numbers and letters.—P. M. C.

Metal Cutters Slowly Gaining on Tough Jet Engine Materials. E. J. Weller. (*S.A.E. J.*, 1954, **62,** Jan., 53–56). This is a general review of metal cutting problems, with notes on the latest developments in tool tip design, prevention of warping, cutting fluids, CO_2 as a coolant, and the machinability of titanium.—P. M. C.

Drilling Stainless Steels. O. Wiederkehr. (*Australian Machinery*, 1954, **7,** Jan., 28–30). Some practical hints are given concerning cutting speeds, drill point design, and lubricants, suitable for drilling various stainless steels.

Introducing: The New Self-Lubricating High Speed Steels. S. G. Fletcher. (*Metal Progress*, 1954, **65,** Feb., 161–166). The development and properties of high-speed steels containing between 0·08 and 0·20% of sulphur are described. Tools made from this type of steel show improved cutting efficiency due to the lubricating action of the sulphide particles in the steel. Improved machinability of the tool steel itself is also obtained. Some uses of these tool steels are given.—B. G. B.

Hard Metals are Machined by New British Ultrasonic Units. (*Machinist*, 1954, **98**, May 1, 753–755). A 50-W. bench-type and a 250-W. pillar-type ultrasonic drilling machine have been developed by Mullard Ltd. Advantage claimed for this type of machine is that it can be used for hard metals, also non-conducting materials. There is no deformation, discoloration, or burning of the workpiece.—M. A. K.

A New Look at Cutting Fluids. H. N. Leave. (*Machinist*, 1954, **98**, Mar. 27, 529–531). Recently developed products make selection of cutting fluids more complex. Methods that help to determine the correct coolant are discussed. Recommendations are made for various materials and include straight oils (sulphurized, fatty, chlorinated) and soluble oils).

Effect of the Coolant on the Quality of the Machined Surface. P. V. Timofeev. (*Stanki i Instrument*, 1953, (9), 21–22). [In Russian]. The results are presented of an investigation of the effect of cooling-lubricating fluids on the extent of transverse surface-roughness in the machining of a structural steel, a tool steel, and a heat-treated heat-resisting steel. The following fluids were used : Paraffin ; paraffin + 0·2% oleic acid ; paraffin + 0·5% oleic acid ; an emulsion containing 2% sulphonated castor oil + 0·5% soda ; and an oil mixture. The effectiveness of the different fluids in producing smoother surfaces is compared for the various steels and machining speeds.—S. K.

Electric-Spark Machining and Repair of Small Dies. E. A. Volodin. (*Stanki i Instrument*, 1953, (8), 21–23). [In Russian]. The technology and economics of the electric-spark machining of dies for dealing with forgings weighing up to 1 lb. are considered. Recent improvements in spark-machining methods are described, their present special advantages for die repairs are outlined and three sets of conditions for such work are enumerated. Available spark-machining installations are criticized, a number of improvements being suggested. The production of electrodes of exactly reproducible dimensions and shapes by powder metallurgy is described, examples being illustrated.—S. K.

Machining by Electro Erosion. L. Walter. (*Canad. Metals*, 1954, **17**, Jan., 45–48). A description is given of a new automatic electro-erosion machine developed by Wickmans Ltd., of Coventry. Twelve examples of the type of work of which the machine is capable and the time for machining are also given.—B. G. B.

Liquid-Abrasive Machining of Metals. K. P. Kochetov. (*Stanki i Instrument*, 1953, (10), 19–23). [In Russian]. A general description of apparatus for the liquid abrasive machining of metals is given together with results of tests on the application of such methods under a variety of conditions to steel and brass specimens of different shapes and initial surface qualities. Well polished surfaces, suitable for subsequent electroplating, could be obtained by liquid-abrasion, such methods being particularly advantageous for complicated shapes and when enhanced resistance to corrosion is required. Wider use of liquid-abrasion machining methods is recommended.—S. K.

The Observation and Control of Dust at Portable Abrasive Wheels and Pneumatic Chisels. W. B. Lawrie, A. T. Holman, and E. B. James. (*Inst. Mech. Eng. Advance Copy*, June 9, 1954).

Clever Bulk Handling Saves Chips and Oil Wastes. (*Machinist*, 1954, **98**, Apr. 24, 692–695). Special features of this oil-recovery and chip-disposal system, operated by Allis-Chalmers Manufacturing Co., U.S.A. includes trackside bins for storing chips and an automatic loading crane.—M. A. K.

Measurement of Surface Finish. (*Tekn. Ukeblad*, 1954, **101**, Mar. 11, 207–109). [In Norwegian]. After defining terms used when measuring surface finish, the author describes briefly the operational principles of the following stylus instruments : Profilometer, Surfindicator, Talysurf, and C. E. Johansson's surface indicator. Optical determination by Schmaltz and interference microscopes are also dealt with.

CLEANING AND PICKLING

Emulsifiable Solvent Cleaning. B. J. Sherwood. (*Metal Finishing*, 1954, **52**, Mar., 70–72). Pre-plating cleaning processes are compared and the operating technique for using emulsified petroleum or kerosene is described.—A. D. H.

Barrel Finishing of Metal Products—The Use of a Slurry in Barrel Finishing. H. L. Beaver. (*Products Finishing*, 1954, **18**, Jan., 24–34). The characteristics of the barrel finishing of steel parts in a suspension of an abrasive is described. Practical details are given.—A. D. H.

Precision Barrel Finishing. M. M. Maynes. (*Plating*, 1954, **41**, Jan., 55–60). Equipment and methods of tumbling in barrels are reviewed. The selection of cleaners and abrasives is discussed and recommendations are made for determining suitable procedures for components.—A. D. H.

Barrel Finishing—More Art Than Science. L. Giglio. (*Machinist*, 1954, **98**, Apr. 17, 653–655). Correct combinations of chip, compound, water and time for efficient barrel finishing are discussed, together with planning procedure for a large shop producing a wide variety of components.—M. A. K.

A Further Study on the Effect of Abrasive Metal Polishing on the Character of Nickel Plate. W. L. Pinner. (*Proc. 40th Ann. Conv. Amer. Electroplaters' Soc.*, 1953, 83–89). The effect of various abrasive polishing procedures on the character of nickel subsequently plated on the steel surface is studied metallographically. The retention of a fine metallic debris is shown to have an adverse effect on the smoothness and corrosion resistance of the deposit. An anodic treatment is beneficial in removing this deposit before plating.—A. D. H.

The Scope of Slidabrading. (*Product Finishing*, 1954, **7**, Feb., 73–76). It is claimed that this improved tumbling process can be applied to ferrous, non-ferrous, and plastic materials for de-burring, polishing or chamfering. Details of the abrasive, barrel speed, and tumbling time are given for a variety of parts in steel, copper and brass.—A. D. H.

Descaling the Stainless Steels. L. F. Spencer. (*Metal Finishing*, 1954, **55**, Feb., 54–59). The author briefly describes mechanical methods for descaling. Seven commercial pickling baths are discussed. Details are given of the operation of 6–8% $Fe_2(SO_4)_3$ and 1·8–2·0% HF solution which gives the lowest metal loss. The sodium hydride process is described.—A. D. H.

Cleaning and Preparation of Metals for Electroplating. VII. Final Summary on Degreasing Evaluation Tests. H. B. Linford and E. B. Saubestre. (*Plating*, 1953, **40**, Nov., 1269–1271). The authors give a review and bibliography of their recent work on the assessment of the efficiency of degreasing.

Surface Preparation by Blast Cleaning Prior to Electroplating. V. F. Stine. (*Metal Finishing*, 1954, **55**, Feb., 65–71). The principles of processes for air blasting, centrifugal blasting and liquid blasting are described. Details of abrasives and pressures are presented with suggestions for efficient practice.—A. D. H.

Maintaining Efficiency in Trichloroethylene Degreasing Plants. E. E. Halls. (*Product Finishing*, 1954, **7**, Mar., 55–69, 118). The author gives a detailed account of the principles and practice of degreasing with trichloroethylene. The properties of the liquid, its attack on materials and the effect of contaminants are discussed. Vapour, liquid and liquid-vapour plants are described with recommendations governing the choice of method. The use of methylene chloride and perchlorethylene is briefly mentioned.—A. D. H.

Chemical Laboratory Speeds Plant Operations. B. Floersch. (*Steel Processing*, 1953, **39**, Nov., 569–572). Examples are given of several new compounds and techniques developed by the chemical laboratory of the Ryan Aeronautical Co. U.S.A. These include : (1) A new pickling procedure for Inconel and type 19–9DL stainless steel, which includes molten caustic salt and subsequent acid treatment ; (2) a soluble oil remover ; (3) an oxide-converter for type 310 stainless steel which facilitates subsequent scale removal by acid pickling ; and (4) a dry lubricant for use with Inconel pressings. No details of the compounds are given.—P. M. C.

Improved Pickling—Economical Working by Means of Ion Exchange. T. R. E. Kressman. (*Australasian Eng.*, 1953, Dec. 7, 58, 59). A method is described for removing the dissolved iron from phosphoric acid pickling liquor, thus enabling the acid to be used over and over again with consequent reduction in cost. The process is based on ion exchange, using a synthetic resin (Permutit " Zeo-Karb 225 "). A column of the resin is charged with hydrogen ions from a solution of sulphuric acid, and after washing off the excess acid with water, the spent phosphoric acid is pumped through the column. The ferrous and ferric phosphates are converted to free phosphoric acid which is passed back to the pickling tank. The Zeo-Karb unit is periodically regenerated with sulphuric acid. The overall cost of pickling is reduced below that for sulphuric acid pickling.—P. M. C.

A New Method of Regenerating Pickling Baths. J. Labergere. (*Mét. Constr. Mécan.*, 1954, **86**, Feb., 127–128). The Ruthner method of regenerating sulphuric acid and hydrochloric pickling baths is considered. For the latter, the ferrous chloride in solution is precipitated by addition of gaseous hydrochloric acid and then treated with steam in a furnace at 400° C. which decomposes it into ferrous oxide and hydrochloric acid. For the former baths, the ferrous sulphate in solution is decomposed with excess hydrochloric acid into sulphuric acid and ferrous chloride, which is precipitated and treated in the same manner as described previously.—B. G. B.

Ultrasonic Cleaning. C. F. Gurnham. (*Products Finishing*, 1954, **18**, Feb., 54–68). A general introduction to methods of producing ultrasonic vibrations is followed by examples of their use in gas cleaning plants. Descriptions are given of installations using ultrasonics for thoroughly cleaning small intricate components. The process is too costly for large articles.—A. D. H.

Theory and Practice of Chemical Polishing, Part 3—The Theory of Chemical Polishing. R. Pinner. (*Electroplating*, 1954, **7**, Apr., 127–131, 140). Continuation of a series of articles (*see J. Iron Steel Inst.*, 1954, **177**, July, 375). The theory of the dissolution of metals in acids is discussed briefly. The importance of film growth in suppressing etch attack is stressed. Chemical polishing solutions are of two classes : (*a*) Those in which the dissolution is under diffusion control and (*b*) dilute solutions of low viscosity which cause periodic formation and dissolution of oxide films.—A. D. H.

Electrolytic Polishing of High-Speed Steels. K. Albinski. (*Prace Instytutow Mechaniki*, 1953, **3**, (7), 42–53). [In Polish]. Experiments on the application of electropolishing to high-speed steel tools showed that their efficiency, based on turning tests, is increased by 20%. Electropolishing conditions for two steels are given.—V. G.

Regeneration of Electrolyte for the Polishing of Steel. N. P. Fedot'ev, E. G. Kruglova and S. Ya. Grilikhes. (*Zhurnal Prikladnoi Khimii*, 1954, **27**, (2), 157–165). [In Russian]. An account is given of researches to find the reasons for the progressive deterioration in the action of a steel-polishing electrolyte, to check this effect, and to regenerate the electrolyte. The deterioration in polishing action is attributed to decreased CrO_3 content, while cessation is connected with accumulation of iron (over 6% Fe_2O_3). Optimum conditions for the anodic oxidation of Cr_2O_3 are stated. Spent electrolyte is said to be regenerated by cathodic reduction at 70–80° C. of hexavalent chromium and trivalent iron, and the precipitation of the resulting bivalent iron as sulphate. Recommended current densities are 0·7–1 amp./l. and 5–10 amp./sq. dm. (cathodic).—S. K.

Metal Pre-Treatment in Antwerp. (*Corrosion Prevention and Control*, 1954, **1**, Mar., 32–34). A brief description is given of what is now the largest plant in the world for the pretreatment and reconditioning of rusted metal ; this was recently opened in Antwerp by Jenolite Ltd. The techniques employed and the construction of the tanks are mentioned.

PROTECTIVE COATINGS

Recent Advances in Electrodeposition. J. W. Cuthbertson. (*J. B'ham. Met. Soc.*, 1953, **33**, Dec., 156–172). The factors influencing deposition process are briefly reviewed with reference to the electrochemical series and the electrode potentials of the common metals on the hydrogen scale. The metallurgy of electrodeposits is then discussed, some observations being made on structure, adhesion, and defects. The production of electrotinplate is next dealt with, information being given concerning the various electrolytes in current use. Reference is made to the production of electrolytic manganese—an outstanding achievement—and the procedures and electrolytes employed in alloy plating. (14 references).—P. M. C.

Metal Finishing in 1953. (*Electroplating*, 1954, **7**, Jan., 4–7). A review is made of the developments in processes equipment and research in electroplating.—A. D. H.

Automatic Process Control in Metal Plating. L. Walter. (*Products Finishing*, 1954, **18**, Feb., 42–52). Methods of heating, temperature control, and solution level control are described.—A. D. H.

An Introduction to Throwing Power and Covering Power in Electroplating Solutions. R. Pinner. (*Electroplating*, 1954, **7**, Jan., 9–15 ; Feb., 49–59). Methods for determining current distribution and throwing power are described. The effect of concentration and chemical polarization modifies the primary current distribution. Covering power is better the higher the applied potential and the higher the initial polarization. It is reduced on rough surfaces. The calculation of throwing power is rarely practicable, but the double-bend cathode test gives a simple, reliable guide to the metal distribution under production conditions. The effects of the type of solution, electrode distance, current density, solution composition, temperature, and the surface structure are given. (42 references).

Temporary Protective Coatings. (*Indust. Finishing*, 1954, **6**, Feb., 501–504). A short review of the scope, nature, and efficiency of coatings used for corrosion protection of stored metals includes oil films, hard and soft grease films, hot-dip coatings, strippable coatings, " cocooning," desiccators and vapour phase inhibitors.—K. E. J.

Plating Small Localized Areas. (*Metal Ind.*, 1954, **84**, Feb. 26, 171–173). The applications and properties of the Dalic process are outlined. The principle of the method is to make the workpiece cathodic by connecting to a specially designed transformer and rectifier unit ; a pad of cotton wool carrying the plating solution is applied to the work by a special anode holder, and the solution is raised to its boiling point by the passage of the plating current. A variety of sizes of anode holders are available, and 19 different metals have so far been deposited from specially prepared solutions which are mainly organic and are different to conventional plating solutions. Many interesting applications include cold welding of copper components for electronic purposes, plating of aluminium, building up worn parts, and deposition of chromium on molybdenum wires in radio valves. The basic cost of the power unit, solutions, and tools is between £200 and £250.—P. M. C.

Decomposition of Cyanides in Aqueous Solutions. W. R. Meyer, R. F. Muraca, and E. J. Perfass. (*Plating*, 1953, **40**, Oct., 1104–1110). Chemical factors causing a loss of alkali cyanides are analysed. Hydrolysis, carbonate formation, oxidation and the formation of complex ions are discussed. Data is presented for the kinetics of decomposition of 5% NaCN solutions. Electrolytic decomposition between inert electrodes is also studied.—A. D. H.

Complex Cuprous Cyanide Compounds. G. Gabrielson. (*Metal Finishing*, 1954, **55**, Feb., 60–75). A review of contemporary reviews on the constitution of copper cyanide ions found in plating baths is given. The author concludes that the $Cu(CN)_3^=$ is the most important constituent.—A. D. H.

Barrel Plating Considerations. E. E. Halls. (*Product Finishing*, 1954, **7**, Feb., 61–72, 112). A general account of the process is given. The type of plant, plating distribution, work-load and current-density are considered.—A. D. H.

The Nature, Cause and Effect of Porosity in Electrodeposits. I. The Porosity of Electrodeposits. F. Ogburn and A. Benderly. (*Plating*, 1954, **41**, Jan., 61–65 ; Feb., 169–173). The porosity of electrodeposited nickel foils has been studied by the gas permeability method. The method is of limited value since the thinnest pore-free films are virtually impermeable. Permeability measurements of specimens selected irrespective of microscopically or photographically detectable porosity are unsuitable because the distribution of pores is not uniform. Foils were exposed to corrosive media and the attack of the film was followed by weight loss and permeability measurements. The results were erratic. In accelerated corrosion tests, 1*N* HCl caused the most rapid rate of surface corrosion whereas 2*N* acetic acid caused extreme pitting.—A. D. H.

The G.K.N. Micro-Hardness Tester in Metal Finishing. (*Electroplating*, 1954, **7**, Apr., 147–148). The instrument is described and its uses in testing coatings are listed.—A. D. H.

Thickness of Electrodeposited Coatings by the Anodic Solution Method. C. F. Waite. (*Proc. 40th Ann. Conv. Amer. Electroplater's Soc.*, 1953, 113–118). Difficulties in conventional tests for chromium plate thickness and the advantages of a modification of the anodic solution method are given. An instrument for industrial use is shown to give rapid measurements of coating thickness.—A. D. H.

An Electronic Thickness Gage. A. Brenner and J. Garcia-Rivera. (*Proc. 40th Ann. Conv. Amer. Electroplaters' Soc.*, 1953, 106–112). An instrument, based on the skin effect, for measuring the thickness of metallic and non-metallic coatings on metals provided that their conductivities differ sufficiently, is described. The thickness of coating that can be measured depends on the frequency of the exciting current. The instrument is direct reading. It can also be used for resistivity measurements.—A. D. H.

Electroplating of Powder Metal Compacts. R. Rushbrook. (*Electroplating*, 1954, **7**, Mar., 92–96). Difficulties in electroplating metal compacts arise if the porosity is greater than 5%. Methods for producing satisfactory deposits and of preventing ingress of electrolyte, or its subsequent removal, are described.—A. D. H.

Chromium-Plating Gun Bores. C. E. McDowell. (*Machinery*, 1954, **84**, Feb. 26, 437–441). A successful production technique has been developed at the Oldsmobile gun factory at Lansing, Michigan, U.S.A. for hard chromium-plating the bores of 90-mm. tank guns. Smooth surface finishes and close tolerances are maintained throughout the 15 ft. length of the barrel tube, and the hard wear-resistant coating ensures improved and consistent accuracy and longer life. In addition to hardness, electrodeposited chromium has a low coefficient of friction, and good corrosion resistance.—M. A. K.

PROPERTIES AND TESTS

The British Five-Ton Deadweight Standard of Load, Installed at the N.P.L. H. V. Pollard and R. G. Hitchcock. (*Engineering*, 1954, **177**, Apr. 9, 468–469). A new 5-ton deadweight standard of load for accurate calibration at the National Physical Laboratory is described.—M. D. J. B.

Ductility and Plastic Deformation. R. L. Stedfeld. (*Machine Design*, 1954, **26**, Mar., 175–183). Limitations in the use of ductility figures obtained from the standard tensile test are outlined. An attempt is made to clarify the design areas in which ductility values can or cannot be accepted as indicating the serviceability of a material. A summary of typical materials and the variations which can occur in those materials is given.—M. A. K.

Influence of Heat Treatment and Cold Working on Tensile Strength Ranges. R. L. Stedfield. (*Machine Design*, 1954, **26**, Feb., 163–173). Methods for raising the tensile strength of a number of materials are summarized. Almost all metallic materials can be worked to increase their strength ; many can be heat-treated. Non-metallic materials usually cannot be heat-treated or worked in the conventional sense of the terms, but other factors which greatly influence tensile strength are discussed.—M. A. K.

Contributions to the Study of the Modulus of Elasticity of Alloys. R. Le Roux. (*Métaux–Corrosion–Indust.*, 1953, **28**, Dec., 489–505 ; 1954, **29**, Jan., 24–36 ; Feb., 66–87). Methods of measuring the modulus of elasticity, both static and dynamic, are first discussed. A detailed examination is made of the Florrison method in which the propagation of ultrasonic wave in a rod clamped in the centre and free at both ends, is measured. The results of a number of experiments carried out on a variety of alloys (including steel) are given and discussed. The results obtained by this method are compared with those obtained by the Rolland-Soren pendulum method and the static method of measurement of increase in length with load, and the relative accuracy of the three methods is discussed in detail. Anisotropic elastic properties are also considered. (105 references).—B. G. B.

A Simple Self-Recording Dilatometer. H. Honda and S. Ito. (*J. Mech. Lab.*, 1953, **7**, Sept., 178–185). [In Japanese]. A dilatometer is described in which the elongation pick-up consists of a phosphor-bronze cantilever fitted with wire resistance strain ganges, and the temperature is measured by an Alumel-chromel thermocouple. The signals, suitably amplified, are displayed on a cathode-ray tube, with a maximum magnification of 600.—J. G. W.

Some Considerations in Steel Testing and Design. W. A. Martin. (*Canad. Metals*, 1953, **16**, Nov., 42–44 ; Dec., 36–38 ; 1954, **17**, Jan., 34–35). A review of the relationship between the performance during mechanical testing and the design of parts is made. The performance of tests to measure the embrittlement of steels which occurs in welded structures is considered. The application of the results of compressive, bending, shear, and fatigue tests on steels are discussed. The recent development of the low-alloy high-tensile steels is reviewed.—B. G. B.

A Method of Using Microwaves for Measuring Small Displacements, and a Torque-Meter Using this Principle. N. C. de V. Enslin. (*Inst. Electrical Engineers, Advance Copy No.* M1632, Dec. 15, 1953). The author describes two methods of employing the relation between the resonant frequency and the dimensions of a resonant cavity to measure small displacements. The principle is applied to the measurement of torque in shafts. Existing methods of measuring torque are discussed. (17 references).—L. E. W.

Investigation of Plastic Strengthening of Notched Bars. E. Siebel and A. Hosang. (*Z.V.d.I.*, 1954, **96**, Feb. 1, 98–101). Experiments were performed with mild steel and Duralumin flat specimens with symmetrically placed semi-circular notches of various radii, with **V**-notches with circular roots, with circular segment notches, and with two round holes spaced halfway between edge and centre line. The tensile tests have shown that the ratio of the 0·2% proof stresses of notched and unnotched specimens is practically equal to the ratio of the maximum and mean tensile stresses as calculated from elasticity theory. The authors conclude that it is therefore permissible to base design on the mean stress, with the working stress being derived from the proof stress of the unnotched material.—J. G. W.

Dislocations, or, What Makes Metals so Weak? W. T. Read, jun. (*Metal Progress*, 1954, **65**, Feb., 101–106). The strength of polycrystalline metals is discussed in relation to the strength of single crystals. The relation between plastic deformation and dislocations is considered ; dislocations being discussed in terms of the slip along crystal planes. The way in which a few dislocations initially present can cause an almost unlimited amount of slip is considered.—B. G. B.

The Existence of Shear and Slip. R. Alexandre and R. Lacroix. (*Génie Civil*, 1954, **131**, Feb. 15, 72–73). An argument is put forward to demonstrate the reality of shear and slip in answer to the recent theory of Vallette to the contrary.

Plastic Deformation in a Steel Cylinder Striking a Rigid Target. E. H. Lee and S. J. Tupper. (*J. Appl. Mech.*, 1954, **21**, Mar., 63–70). The development of a theory of propagation of plastic waves for a high-strength alloy steel permits calculations of strain distribution agreeing well with observed dynamic compression tests. Although the Taylor method of firing a missile at hardened armour-plate is normally employed for determining dynamic yield stress, its use in the present investigation has provided a satisfactory static relationship.—J. O. L.

Internal Microstrains and the Deformation and Failure of Metals. L. J. Dijkstra, U. Martins, B. Chalmers, and P. E. Cavanagh. (*Nondestructive Test.*, 1954, **12**, Jan.-Feb., 13–18). A powder pattern technique for studying static ferromagnetic domain patterns is described. A colloidal suspension of magnetite is placed on the surface to be examined after very careful preparation. The stray fields arising between the regions of different magnetization attract the colloid, thus rendering the domain walls visible. The study of such domain patterns, which are very sensitive to strains in the material, provides a very useful tool for the determination of states of strain during plastic deformation and fracture. Many typical patterns are illustrated and analysed.

Determination of Residual Surface Stresses with the Aid of Resistance Wire Strain Gauges. S. Sjöström. (*Appl. Sci. Res.*, 1954, **4A**, (4), 305–312). Details and applications of a method of surface stress determination are described. Thin layers are removed by polishing from one side of flat test bars and the change in strain on the opposite surface is measured. An expression is derived relating the change in strain to the initial residual stress.—E. C.

Recording Signals from Resistance Strain Gauges. D. A. Senior. (*Engineer*, 1954, **197**, Mar. 19, 410–413 ; Mar. 26, 446–449 ; Apr. 2, 482–483). The author describes a method of recording the signals from resistance strain gauges by using sensitive moving-coil galvanometers. An exprimental galvanometer is described which works with a strain gauge dissipating 4W. and covers a frequency range from 0 to 65 cycles/sec. Various strain gauges to be used with galvanometers and capable of dissipating high powers are described, including one consisting of four 800-ohm gauges in parallel which has proved satisfactory at powers up to 4W. Details are also given of a 12-channel direct strain recorder.

Characteristics and Applications of Resistance Strain Gages. (*National Bureau of Standards Circular* 528, Feb. 15, 1954). The National Bureau of Standards arranged 12 symposia in 1951 to mark the fiftieth anniversity of its establishment. One of these, held on Nov. 8 and 9, 1951, was on Resistance Strain Gages, and the proceedings are recorded in the present 140-page book. The principle papers of interest were :

Poisson-Ratio Determinations for Elastic and Plastic Strains of Tensile Specimens. J. Vigness and T. E. Pardue, (1–9).

Cementing and Waterproofing of Resistance Strain Gages. R. G. Boiten. (11–30).

Unbonded Resistance-Wire Strain Gage. L. Statham. (31–40).

A New Strain Gage without Transverse Sensitivity. A. U. Huggenberger. (78).

How to Use G-H Gages. G. V. A. Gustafsson. (79–91). This new Swedish gauge is one without a paper base; it is free from transverse sensitivity. A transparent plastic base permits visual inspection of bonding conditions. The initial letters in the name are those of A. U. Huggenberger and the present author. These gauges are also known as Tepic gauges and Sweden gauges.

Bonded-Wire Strain Gage in the Field of Instrumentation. A. C. Ruge. (93–108).

Commercial Weighing with Resistance Strain Gages. A. L. Thurston. (109–120).

Application of Resistance-Wire Strain Gages to High-Capacity Load-Calibrating Devices. D. R. Tate. (121–130).

Preliminary Investigation of the Strain Sensitivity of Conducting Films. W. R. Campbell. (131–140).

The Failure of High-Pressure Fuel Pipes on Compression-Ignition Engines and Its Prevention. (*Shipbuilder and Marine Engine-Builder*, 1953, **60**, Dec., 677–680). After a short statement on present practice, the results of laboratory investigations into pipe failures are presented. These are followed by recommendations for pipe installations.—R. P.

Fatigue Tests of Spot Welds in Cor-Ten and Mild Steel. G. Welter and A. Choquet. (*Welding J.*, 1954, **33**, Mar., 134s–140s). Fatigue tests were carried out on multiple resistance welded Cor-Ten steel 0·042 in. and mild steel 0·037 in. thick. Total and permanent microdeformations under increasing loads have been investigated and the results correlated with those of the endurance tests.—U. E.

Increasing Fatigue Life of Investment-Cast Medium-Carbon Steel. (*Iron Coal Trades Rev.*, 1954, **168**, Mar. 12, 628). Recent American research work shows that the endurance limit of decarburized, investment-cast 0·30–0·45%-C steel may be improved in certain cases by restoring the carbon of its decarburized surfaces. The results are briefly summarized.—G. F.

Definition of Fatigue Resistance in Welded Steel Structures. (*Cien. Tecn. Solda.*, 1953, **111**, Nov.-Dec.). [In Spanish]. This document is edited by Committee 13 (Fatigue Tests) of the International Institute of Welding and comprises material agreed at the International Congress, Copenhagen, July, 1953. Fatigue strength in a welded member is the weight it can bear for 2,000,000 cycles. The standard method of determining this load is described and interpretation of fatigue test results is discussed.—C. B. L.

Fatigue of Welded Structures. R. Weck. (*Structural Eng.*, 1954, **32**, Apr., 115–129). The author covers the general aspects of fatigue failure in buildings, bridges, and machinery structures, and describes the appearance of fatigue failure. Some fundamental facts concerning metal fatigue are discussed in terms of the stress/cycles diagram and its significance, the notch effect, fatigue limit, effect of mean stress, corrosion, and the fatigue properties of high tensile steel (13 references).

Magnetic Measurement of Mechanical Hardness. D. Hadfield. (*Inst. Electrical Engineers, Advance Copy* M1596, Oct. 12, 1953). The author describes a new method for the non-destructive measurement of the mechanical hardness of ferromagnetic components, based on the relationship between a 'coefficient of magnetic hardness' and the variables in the upper portion of the magnetization curve. It is shown that there is a direct relationship between the magnetic permeability and the mechanical hardness of a low-alloy steel, and this is used as the basis of a D.C. magnetic method of hardness measurement for two steel components of diverse character. The construction and performance of portable apparatus is described in detail and test results obtained are discussed. The reproducibility of readings is better than 1% and almost linear correlation between instrument reading and mechanical hardness is obtained.—L. E. W.

On the Behaviour of Hardness-Curve of Quenched Steels (II). T. Mishima and T. Mitsuhashi. (*Tetsu to Hagane*, 1951, **37**, Apr., 212–215). [In Japanese]. The decrease in hardness caused by higher quenching temperatures is mainly attributed to decarburization and increase in the amount of retained austenite; grain growth is a minor factor. A mathematical relation exists between hardness and grain size for several martensitic alloy and high carbon steels.—K. E. J.

Effect of the Hardenability of a Tool on Crack Formation. E. I. Malinkina. (*Stanki i Instrument*, 1953, (8), 23–27). [In Russian]. The investigation described aimed at formulating the conditions leading to cracking in a tool steel in relation to the cross-section, and consequently the hardenability of the tool. The steel was a 1%-carbon tool steel. As-cast its microstructure was a mixture of granular and lamellar pearlite. Frequency of crack formation in heat-treated specimens of sections and the distribution of hardness were found for hardening temperatures in the range 750–1000° C. The conditions leading to the formation of different types of crack are summarized in two diagrams.—S. K.

Studies on the Hardenability of Boron Steel (I), On the Boron Treatment of Commercial Carbon Steel. T. Mitsuhashi, K. Tsuya, and Y. Sakami. (*J. Mech. Lab.*, 1954, **8**, Jan., 1–7). [In Japanese]. The effect of boron on the hardenability of 0·4%-carbon steel was studied. The isothermal transformation diagram, austenitic grain size, and Jominy curve, were determined. The continuous cooling diagram of boron-treated steel was established by the Jominy end-quench method. The presence of intermediate structures was established and the mechanism of their formation is discussed.—J. G. W.

Hardenability of Unalloyed Tool Steel and Its Determination. H. Schottky. (*Z.V.d.I.*, 1954, **96**, Feb. 21, 165–169). Following a general discussion of surface and deep hardenability, the author surveys existing knowledge of this subject and the method of testing with application to straight carbon tool steels. (28 references).—J. G. W.

Hardenability and Tempering Quality of Constructional Steels and Their Determination. H. Schottky. (*Z.V.d.I.*, 1954, **96**, Mar. 1, 195–202). This is a survey of methods and procedures by which the hardenability and tempering quality of constructional steels can be determined. (41 references).

Hardness of the γ Solid Solution of the Iron-Carbon System at High Temperatures. K. A. Osipov and E. M. Miroshkina. (*Doklady Akademii Nauk S.S.S.R.*, 1954, **94**, (6), 1065–1067). [In Russian]. A study of hardness of iron–carbon solid solutions in the temperature range 910–1100° C. is described. The chemical compositions of specimens and experimental procedure are given. At high temperatures with short indentation time, the hardness of the austenite increased with increasing carbon content.—V. G.

Microhardness Measurements. F. Staub and A. Rosciszewski. (*Prace Instytutow Mechaniki*, 1953, **3**, (7), 54–69). [In Polish]. A review of the most frequently used hardness measuring methods is given. The principles of correct microhardness measurement are discussed. The Girschig's microhardness tester is described and its superiority over Bergman's instrument is stressed. The results of microhardness measurements on ferrite, pearlite, martensite, cementite, and other structures of steel and cast iron are given.—V. G.

The Influence of Transformation of Intercrystalline Substances on the Properties of Mild Carbon Steels. Z. Wusatowski. (*Prace Instytutow Mechaniki*, 1953, **3**, (8), 11–64). [In Polish]. Considering in turn the problems of grain and grain boundaries in steel and the appearance of stresses in the initial stages of cold working, the author discusses the influence of heat-treatment and the chemical composition of steel on the phenomena of the double yield point aud blue brittleness. The precipitation of the tertiary carbide is the main cause of ageing; and after rapid cooling the precipitation of nitrides also causes ageing after cold working. To confirm his conclusions the author examined recent experiments with single crystals of pure iron and the influence of hydrogen reduction on the properties of mild steel. (187 references).—V. G.

A Quantitative Measure of Temper Embrittlement. N. Brown. (*Trans. Amer. Inst. Min. Met. Eng.*, 1954, **200**; *J. Met.*, 1954, **6**, Mar., 361–365). From consideration of the theories of flow and fracture, the author shows that the difference in reciprocals of the transition temperatures (° K) is a quantitative measure of temper embrittlement. Experimental data supporting this conclusion are given.—G. F.

Study on the Friction between Steel and Soil. (I). H. Nagao and T. Minami. (*Tetsu to Hagane*, 1951, **37**, Sept., 477–480). [In Japanese]. Eutectic steel water-quenched at 770° C. showed least wear. In steels of the same carbon content,

those with higher hardness wore least ; with equal hardness, those with higher carbon contents wore least.—K. E. J.

Graphite Lubrication in Grey Cast Iron. E. Knuth-Winterfeldt and E. Langer. (*Nature*, 1954, **173**, Mar. 13, 497–498). Depending on the possibility of the cast iron adsorbing water vapour, two types of track are obtained on sliding a tungsten carbide ball over a cast-iron surface. In the absence of water vapour a continuous track of deformed graphite is formed. The other type of track is metallic in appearance and corresponds to the build up of an insulating film.—A. G.

A Reply to a Criticism of the Increasing Load Wire Abrasion Tester. H. T. McLean. (*Wire and Wire Prod.*, 1954, **29**, Feb., 169, 198–199). Criticisms of this tester made by F. Levi, are considered. It is admitted that the increasing load tester is less sensitive than the repeated scrape tester, but it is defended on the grounds of quicker results of sufficient reliability for practical purposes.—J. G. W.

Abrasive Wear of Metals at Various Temperatures and Speeds. G. I. Kiselev. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **87**, (5), 735–737). A study of the relationship between the abrasive wear of metals and their tensile strength at various temperatures is described. Investigations were made with plain carbon steels (containing from 0·2 to 1·2% of carbon), copper, and zinc.—V. G.

Permanent Magnet Steels and Alloys. D. Hadfield. (*Metal Treatment and Drop Forg.*, 1954, **21**, Jan., 15–24). The various magnetic criteria, (remanence, coercivity, $BH_{max.}$) are described briefly, and an outline follows of the history of permanent magnet materials, tracing their evolution from the origin of tungsten steel 70 years ago to those available today, when the energy a given volume of material can produce has increased in one instance thirtysevenfold, ($BH_{max.}$) = 6·8 to 7·8 for modern Co–Al–Ni–Cu alloys). Trade names, compositions, and magnetic properties are tabulated for many materials during the period under review. The manufacture of magnet steels and alloys, production processes, and possible future trends are discussed. (18 references).

Magnetic Viscosity in Precipitation Alloys: FeNiAl, Fe_2NiAl and Alnico. J. H. Phillips, R. Street, and J. C. Woolley. (*Phil. Mag.*, 1954, **45**, May, 505–523). The effects of various heat-treatments on magnetic viscosity were studied, and the results interpreted in terms of the thermal activation theory Neél's disperse field theory and Giesler's theory of coherency hardening. Magnetic viscosity methods can be used to investigate precipitate and magnetic structures of the order of 10^{-17} c.c. in volume. The thermal activation theory is valid at least over the temperature range 90–900° K.—K. E. J.

Ultrathin Tapes of Magnetic Alloys with Rectangular Hysteresis Loops. M. F. Littmann. (*Trans. Amer. Inst. Elec. Eng.*, 1952, **71**, Part I, 220–223). The magnetic properties of toroidal cores wound from ultra-thin tapes of four alloys (*a*: 3%-silicon iron, *b*: 48/52 Ni–Fe, *c*: 79/4/17 Ni–Mo–Fe, *d*: 79/5/16 Ni–Mo–Fe) were studied using D.C. magnetization. The D.C. hysteresis loops obtained were almost rectangular. The coercivity of these thin tapes is usually lower than that of ferrites or powdered metals.—R. A. R.

The Determination of the Texture of Sheet Steel from Torque Curves. L. R. Blake. (*Brit. J. Appl. Phys.*, 1954, **5**, Mar., 99–104). The torque curve is used extensively to check whether the i 'eal orientation for optimum magnetic properties in silicon-iron sheet ($\{110\}$ crystallographic plane in plane of sheet, $< 100 >$ edge in direction of rolling) has been attained. Used in conjunction with X-ray data, the method proposed here can be employed for rapid calculation of the degree of orientation, while valuable deductions can be made even without X-ray examination.—J. O. L.

On the Variation of Permeability of Irons and Steels as a Function of the Mechanical Stresses. J. Creusot. (*Compt. Rend.*, 1954, **238**, Mar. 15, 1203–1204). The variation has been studied of the induction B of samples of irons and steels in a constant magnetic field and under a variable mechanical tension T. According to the operating conditions, the curves $B = f(T)$ may show a levelling off whose extremities correspond to values T_1 and T_2 characteristic of the sample.—A. G.

Ultrasonic Testing of Mass Products in Water Immersion. J. Keller. (*Acta Techn.*, 1953, **7**, (3–4), 359–387). [In English]. An automatic ultrasonic apparatus for testing hollow cylindrical parts under water is described; it incorporates a flaw recording device. (29 references).—R. A. R.

Application of Ultrasonic Flaw Detection Method for Material Testing. (II). Ultrasonic Attenuation in Polycrystalline Steel. A. Hikata. (*J. Mech. Lab.*, 1954, **8**, Jan., 45–52). [In Japanese]. An investigation of the ultrasonic attenuation in polycrystalline steels subjected to a magnetic field and to stress has shown that the attenuation decreases with increasing field strength ; in fully annealed steels it decreases with increasing tensile or shear stress up to the yield stress, and then decreases abruptly. In cold-worked steels the attenuation initially increases and then decreases with increasing magnetic field strength. It is believed that some relation exists between ultrasonic attenuation and the dislocation mechanism.—J. G. W.

Ultrasonic Attenuation in Polycrystalline Steel. A. Hikata. (*Government Mechanical Laboratory Bull., Tokyo*, 1954, No. 1, 1–7). [In English]. The author shows how the attenuation of ultrasonic waves in steels changes when the specimens are magnetized or stressed. The apparatus used is described and details are given of the compositions and heat-treatments of the materials investigated, and the dimensions of the test-pieces employed. The results obtained are presented in graph form and are briefly discussed. (12 references).

Non-Destructive Testing. W. H. Plews and P. Fox. (*Anvil*, 1954, **3**, Spring, 4–7). The principles involved in magnetic surface crack detection, ultrasonic testing, and X-ray and gamma-ray examination are dealt with and the precautions to be observed are indicated.—L. E. W.

A Controllable Permanent-Magnet Crack Detector. J. W. Walley. (*Metro. Vick. Gaz.*, 1953, **25**, Nov., 106–107). The author describes a new design of magnetic crack detector developed by Metropolitan Vickers for components being examined for transverse faults. The detector is similar in appearance and operation to a small capstan lathe. A sheet steel drip tray is surmounted by a steel bedplate which carries a fixed magnet head and a sliding spring-loaded head. The fixed magnet head is a hollow cylinder and contains the permanent magnet. The new design embodies a spring-loaded faceplate giving sufficient end pressure to hold the component under test, the spring pressure being controlled by a ball handle. The detector may be easily adapted for longitudinal faults.—L. E. W.

A Description of Industrial Radiography. R. E. MacDonald. (Engineering Inst. of Canada : *Canad. Metals*, 1953, **16**, Nov., 46–47 ; Dec., 40–41 ; 1954, **17**, Jan., 36–37). Several examples are given of the use of radiography for the inspection of welds, particularly in all-welded vessels of the Royal Canadian Navy. The use of CO_{60} for radiography is discussed and details of the precautions taken to safeguard the health of the operators are given.—B. G. B.

Notes on Industrial Radiology. A. Ruiz Rubio. (*Cien. Tecn. Solda.*, 1953, **111**, Nov.-Dec.). [In Spanish]. This paper is equivalent to a short text book, describing physical principles and techniques. Its main sections are : Physical principles ; exposure factors ; reaction of X-rays on emulsion ; and protection against X-rays.—C. B. L.

Radiographic Characteristics of High-Energy X-Rays. A. L. Pace. (*Foundry*, 1954, **82**, Feb., 108–111, 178). X-rays produced at voltages greater than 2 meV. are now being used for the radiography of thick sections of steel. The penetration of the radiation in steel is greatest at 14 meV. and decreases for higher voltages. With equipment operating at high voltages little of the energy of the electrons is converted into heat so that the size of the focal spot can be kept to a minimum. High-energy X-rays also give improved contrast by reducing the amount of oblique scatter. Betatron equipment used for producing high-energy X-rays is briefly described and its applications discussed.—B. C. W.

X-Ray Focal Spot Measurement. D. Polansky and D. T. O'Connor. (*Nondestructive Test.*, 1954, **12**, Jan.-Feb., 37–40). The pinhole image of X-ray focal spots over a wide range of voltage is discussed. Variations in pinhole size, density, and magnification appear to be small compared with the inaccuracy of direct visual measurement of blurred focal images. Klasen's method of film trace evaluation of blurred contours by microdensitometry is applied to images of known sources, and it is shown to give a more realistic value (within 5%) than that obtained by direct visual measurement.—P. M. C.

Plastic Positioner Fits Irregular Parts. E. R. Foor. (*Steel*, 1954, **134**, Mar. 1, 116–118). An appliance of the Solar Aircraft Co. called " Flexi Cast " enables irregular shaped parts to be held easily in a suitable position against an X-ray film

for exposure. A bag can be moulded to the shape required for holding work, and made rigid by evacuating air.—D. L. C. P.

An Introduction to Radiographic Examination of Welding. E. J. Barnard. (*New Zealand Eng.*, 1953, **8**, Dec., 420–432). A concise description of the background of radiography and the techniques required for both X- and gamma-ray work is given. This includes the problems encountered when deciding on suitable equipment and in the protection of operators. Then follows a description of the examination of dock-gate lifting cylinders and of the Cobb River Valley penstock. Reproductions from radiographs showing typical weld defects are given. (16 references).—P. M. C.

Non-Destructive Testing of Structures. L. J. Oye. (*Welding J.*, 1954, **33**, Mar., 223–233). A survey is given of the development and economics of inspecting welded structures with magnetic particles, penetrating fluids, and electronic devices.

Non-Destructive Tests of Field Welds on Welded Pipe Lines. J. H. Lawson. (Welding Engineering Symposium : *Australasian Eng.*, 1954, Jan. 7, 57–60). A general account is given of the field testing of welds by radiography, using radioactive isotopes as source units. The use of penetrameters is described and typical weld defects are listed together with details of their appearance on the radiograph. Brief notes are given on films, screens, cassettes, processing, and exposure times.—P. M. C.

Non-Destructive Test Methods for Inspection of Welded Joints. R. J. Krieger, S. A. Wenk, and R. C. McMaster. (*Welding J.*, 1954, **33**, Mar., 154s–160s). The non-destructive test methods applicable to flaw delection in welds in ship's structures, such as radiography, magnetic particle, ultrasonics, and penetrating fluids are reviewed.—U. E.

Researches on Welded Pressure Vessels and Pipelines. N. Gross. (*Brit. Welding J.*, 1954, **1**, Apr., 149–160). The paper deals with strain measurements in pressure vessels, in connection with stress peaks in drumheads and around large openings such as nozzles. The effects of reinforcements around nozzles are discussed. Measurements were made on full-scale specimens, both on the inside and the outside surfaces of the vessels, using electric resistance gauges and stress probing. The results of pulsating-pressure tests on pipeline components are described. Limitations of strain-gauge measurements in the design of welded pressure vessels are dealt with.—U. E.

Effect of Reinforcement on Performance of Weldments. C. E. Hartbower. (*Welding J.*, 1954, **33**, Mar., 141s–146s). Mild steel weldments joined with E6010 and E12016 electrodes have been subjected to balanced bi-axial loading over a range of testing temperatures. The tendency to fracture was compared with and without weld reinforcements. The tendency to produce brittle fractures was more reduced when the welds were ground flush than when weld reinforcements were left intact. A rise in the brittle-ductile transition temperature of approximately 80° F. resulted from the presence of the reinforcement.—U. E.

An X-Ray Diffraction Method for the Measurement of Internal Stresses in Metals. I. Szántó. (*Acta Techn.*, 1953, **7**, (1–2), 165–186). [In German]. Two new methods are described : One involves mathematical evaluation from the relative position of both lines in the K_2 double ; the second method uses a new camera for the direct measurement of reflection angles. The main advantage of these methods over previous ones is that the distance between the plane of registration and the surface of the specimen need not be known accurately. (15 references).—R. F.

Radioisotope Techniques. (*Proceedings of the Isotope Techniques Conf.*, Oxford, July 1951, vol. 2 : Ministry of Supply, 1952, reprinted 1953). This, the second volume recording the proceedings of the Conference, contains the papers and discussions on industrial and allied research. The papers of interest to the iron and steel industry are :

Types of Applications of Radioisotopes. H. Seligman. (1–5).

Radioactive Isotopes Applied to Metallurgical Research. R. W. Cahn. (15–22).

Investigation of Wear of Metals by Radioactive Methods. M. Kerridge. (26–34).

A Study of Tracer Methods for Assessing the Wear of Wire-Drawing Dies. J. C. E. Button, A. J. Davies, and R. Tourret. (34–46).

The Handling of Radiographic Sources. W. S. Eastwood. (48–51).

Radioisotopes in Radiography and Wall Thickness Measurement. B. Schuil. (51–54).

Non-Destructive Examination of Steel Castings. F. Cousans, H. Peiser, and J. R. Rait. (54–57).

Notes on Inspection of Iron and Steel Castings. R. J. Hart. (57–60).

Observations on the Gamma-Ray Examination of Steel Castings and Welds. T. Watmough and D. Leonard. (60–66).

Radiography of Pipe Welds with Isotopes. J. G. M. Turnbull. (66–71).

Safety Precautions with Radioisotopes. J. S. Blair. (71–72).

Counters with Thin Plastic Walls for the Detection of Soft X-Rays from an Extended Source. S. G. Cohen and D. Carmi. (73–75).

The Use of Radioactive Isotopes in an Analogue Computer for Stochastic Problems. H. Herne. (75–79). "Stochastic" is a new term for which there is no satisfactory alternative ; it means 'random', particularly in the 'random in time' sense. The computer described was built to simulate a storage system where material is supplied in bulk at random intervals and is consumed at a steady rate.

Absolute Measurement of the Activity of Radioisotopes. J. L. Putman. (79–89).

The Study of Solid Reactions. R. Lindner. (90–94).

Studies on Complex Formation by the Use of Radioactive Tracers. J. Rydberg and D. Dyrssen. (95–100).

The Application of Isotopes to the Examination of Industrial Materials. K. Fearnside. (138–144).

Inspection and Gauging with Ionizing Radiations. G. Syke. (144–149).

Some Indications of the Scope of Radioactivation Analysis. A. A. Smales. (162–177).

Industrial Examples of the Use of Radioactive Isotopes. C. Van de Casteele. (*Rev. Tech. Luxembourg*, 1954, **46**, Jan.-Mar., 28–35). A short account of some uses to which radioactive isotopes have been put in industry, is given. The examples cited include diffusion studies and radiography.

High-Temperature Steam Pipes—Properties of Steels and Basis of Design. P. H. Margen. (*Engineering*, 1954, **177**, Apr. 9, 457–461). The author discusses the need for up-to-date steel specifications for steel tubes for high-temperature service. The properties of the main high-temperature steel are reviewed, and the suggested working stresses are applied to design problems.—M. D. J. B.

Effect of Supersonic Waves on Various Changes of Steel at High Temperature. S. Tanaka, T. Yoshida, and K. Takagi. (*Tetsu to Hagane*, 1951, **37**, Oct., 527–532). [In Japanese]. The effects of 100 kilocycle waves on 1·2% C strip were to accelerate transformation, to produce a mixed grain structure (possibly through interference), to concentrate cementite at the grain boundaries, and to accelerate oxidation and decarburization in air.—K. E. J.

These Curves Show Strength of New Heat Resistant Alloy. M. N. Ornitz and R. H. English. (*Mat. Methods*, 1954, **39**, Jan., 82–85). The high temperature properties and uses of the new casting alloy NA22H developed by the American Blaw-Knox Co. are described. The composition is 0·50% C, 48% Ni, 28% Cr, 5% W, balance iron. The alloy is superior in structural stability and oxidation resistance to other standard nickel–chromium compositions, and is suitable for service up to 2200° F. Typical applications are radiant tubes for heat-treatment furnaces, retorts, high temperature muffles and fans, and electric heater and baffle support bars.

High Performance Jet Engine Design Dependent upon Metallurgical Ingenuity. I. Perlmutter. (Amer. Inst. Min. Met. Eng. Elec. Furn. Steel Conf. : *J. Met.*, 1954, **6**, Feb. Section I, 113–118). The requirements of high performance jet engines offer a challenge to the metallurgist in his ability to provide suitable materials and special design data required by the designer. The author discusses some of these requirements and indicates the progress made in the development of the materials.—G. F.

Materials for High Temperatures Service. H. C. Cross. (*Indust. Heating*, 1953, **20**, Oct., 1986–1996 ; Dec., 2416–2420). The properties of aluminium, titanium, chromium and molybdenum alloys are discussed.—R. W. B.

Study of Certain Mechanical Properties of Alloys Close to the Fusion Point. C. Boulanger. (*Compt. Rend.*, 1954, **238**,

Mar. 1, 1024–1026). The use of a hysteresis meter for studying the internal friction and Young's modulus of alloys close to their melting point is described. It has been employed on aluminium and its alloys and an attempt is made to apply the results to steels in order to explain the phenomena of overheating and burning.—A. G.

Scatter of Results of Creep-Rupture Tests on Heat-Resisting Steels. H. Zschokke. (*Brown-Boveri Rev.*, 1953, **40,** May-June, 199–209). The author describes rupturing tests on rolled steel bars and forgings of various compositions. The results are presented and discussed and an attempt is made to separate the factors causing their scatter. It is concluded from the 38 ferritic steel forgings and 68 rolled austenitic steel bars investigated that: (1) Experimental errors expressed in kg./sq. mm. caused by loading errors and faults in temperature measurement are greater the more rapid the decrease of strength with rising temperature; (2) in rolled bars and forgings the material differences in one piece are less than the experimental error; (3) in rolled bars and forgings the differences between pieces are greater than the sum of the experimental error and material differences in one specimen; and (4) the total percentage of rupture-strength scatter increases very little with testing time for ferritic forgings but very rapidly for austenitic rolled bars.—L. E. W.

A Yield Point in Steel Due to Hydrogen. H. C. Rogers. (*Acta Met.*, 1954, **2,** Jan., 167). [In English]. Brief details are given of the detection of a yield point in specimens tested below −120° C.—A. D. H.

On the Behaviour of Hydrogen in Steel. (II). M. Kawai. (*Tetsu to Hagane*, 1951, **37,** Jan., 23–29). [In Japanese]. A discussion is presented of the hydrogen pressure in cavities and the effect of cavities on diffusion. In the theoretical equilibrium case, the pressure reaches its maximum at approx. 150° C. The hydrogen pressure is great in the segregated zone, after the $\gamma \rightarrow \alpha$ transformation, and this may explain the flake formation. Where the total volume of cavities is large, diffusion and escape of hydrogen are considerably retarded.—K. E. J.

The Influence of Nitrogen on the Properties of Steels. F. Maratray. (*Doc. Mét.*, 1953, Oct.-Nov.-Dec., 127–173). This is a comprehensive review of the occurrence and effects of nitrogen in iron, plain carbon steels and alloy steels. Among the aspects considered are: (*a*) The Fe–N system and the transformations of nitrogen martensite; (*b*) the effect of nitrogen on quench and strain-ageing; (*c*) the solubility of nitrogen in liquid iron and the effects on this of various alloying elements; (*d*) the influence of nitrogen on mechanical properties and hardenability of carbon steels; (*e*) the effect of nitrogen on Cr, Ni–Cr, Mn and Cr–Mn steels; and (*f*) nitriding and nitriding steels. (143 references).—B. C. W.

An Application of Atomic Chemistry in Metallurgy—Nitrogen Steels. A. Roos. (*Chim. et Ind.*, 1954, **71,** Feb., 277–280). Nitrogen, having an atomic radius close to that of carbon, makes it possible to obtain quenched structures with high mechanical strength and hardness. Such nitrogen steels, made by fusion, can effect a considerable saving in nickel both in stainless alloys and tool steels.—A. G.

Influence of Oxygen on the Properties of Iron and Steel. (II). T. Saito. (*Tetsu to Hagane*, 1951, **37,** May, 283–290). [In Japanese]. The effects of oxygen on grain growth, structure and hardenability of nickel steels were determined. Nickel counteracts the deleterious effects of oxygen on steel. However, nickel steels must be made with high oxygen contents to eliminate flaking due to hydrogen.—K. E. J.

Effect of Each Element on the High Chromium High-Speed Steel. S. Koshiba. (*Tetsu to Hagane*, 1951, **37,** Sept., 472–477; Oct., 532–536). [In Japanese]. The results of varying the elements were studied on a steel containing 1·4% C, 10% Cr, 4% W, 1% V and 5% Co. The compositions within the range 1·2–1·4% C, 10% Cr and 4% W (vandaium and cobalt contents not being varied) gave moderate results. Vanadium contents of 1·8–2·0% gave the best results, and cutting durability increased as the cobalt content increased in the range 0–10%. (22 references).—K. E. J.

Boron Steels—Production and Use. (*Organisation for European Economic Co-operation, Technical Assistance Mission*, No. 124, Mar. 1954). This article deals with the production and uses of boron steels and includes a summary of the discussions between European and American experts. The economic aspects of boron production are briefly discussed and details are given of the effects of boron on the properties and microstructure of steels, its behaviour in the furnace, the sequence of operations in typical furnace practice, and the most satisfactory alloy forms in which boron is added to the melt. The optimum range of boron content is considered in relation to hardenability and it is stressed that the only reliable test of the success of the boron treatment is the end-quench hardenability test. The economic background to the development of boron steels and other low-alloy steels is discussed. (23 references).—L. E. W.

A Pinch of Boron Doubles Yield Point of Low-Carbon Steel. (*Steel*, 1954, **134,** Feb. 22, 107–110). The composition, properties and uses of the United Steel Company's "Fortiweld" are briefly set out. The main appeal of this steel (0·14% max. C; 0·40–0·60% Mo; 0·0015–0·0035% soluble B) is its combined weldability and strength. Some test results are given relating to Kaiser Steel Corporation's molybdenum-boron steel.—D. L. C. P.

Researches on the Special Cast Steel. H. Mikashima. (*Tetsu to Hagane*, 1951, **37,** June, 352–358; July, 412–420, Aug., 466–472; Oct., 512–516; Nov., 595–600; Dec., 632–641). [In Japanese]. The addition of silicon to Cr–Mo cast steel improves the mechanical properties, and the optimum silicon additions for various carbon contents were determined. Cast Cr–Mo–Si steels, after tempering, have equivalent properties to the forged steels. During the peritectic reaction, the fineness of the grains depends on the degree of diffusion, the fluidity, and the thermal conductivity. Dendritic segregation is not affected by annealing or quenching just above the Ac_3 point, but it is dispersed by normalizing at higher temperatures. In general, adding silicon to Cr–Mo steels impedes the diffusion of dendritic segregation, while nickel additions have little effect. The mechanical properties, particularly impact resistance, improve as dendritic segregation is diffused, whether by high temperature normalizing or by repeated normalizing treatments. Grain coarsening at various temperatures was observed when manganese was added to Cr–Mo steel, and Cr to Mn–Si steel; with additions of silicon titanium or aluminium to various steels, it was only observed above 1100° C. Additions of silicon, tungsten, vanadium, titanium, or aluminium have a marked effect on grain refining and grain growth inhibition, but nickel or manganese additions have no such effects. (42 references).

The Influence of Zirconium on Iron and Steel. M. Hasegawa. (*Tetsu to Hagane*, 1951, **37,** May, 272–283; Nov., 579–588). [In Japanese]. Results obtained were: Zirconium reduces blowholes, and the oxygen and nitrogen in the ingot, the deoxidation effect being stronger than that of silicon; the desulphurizing effect is stronger than that of manganese. Zirconium refines the austenitic grain size and retards grain growth at high temperature. With 0·5–0·9% Zr, there is little effect on the A_1 point, but it slightly lowers the A_3 point; in many cases the annealed and normalized structures are refined, but there is little effect on quenched and tempered structures; the mechanical properties of normalized or high-temperature tempered steels are improved by up to 0·5% Zr, it raises the toughness of low-temperature tempered steel and prevents temper-brittleness in low-alloy structural steels. Deoxidation by zirconium improves the low-temperature brittleness of steel.—K. E. J.

A Study of Zirconium in Steel. T. Mishima and T. Mitsuhashi. (*Tetsu to Hagane*, 1951, **37,** June, 345–352). [In Japanese]. Zirconium additions depress the Ac points of high-carbon steels, and produce secondary hardening, particularly when silicon and chromium are present. Zirconium refines austenitic grains, produces spheroidal cementite in pearlite, and has a retarding effect on the tempering of quenched steel. (11 references).—K. E. J.

On the Behaviour of Copper in Steel Oxidized at High Temperature. T. Mitsuhashi, M. Ueno, and Y. Hosoi. (*J. Mech. Lab.*, 1953, **7,** Nov., 239–248). [In Japanese]. The effects of 0·16 to 1·17% copper on the hot workability of spring steel were examined when keeping specimens at a high temperature in an oxidizing atmosphere. Surface cracking appeared to be related to copper content, temperature and holding time, and the degree of scaling. Tensile strength at 1200° C. decreases with increasing copper content. The reason for surface cracking is to be sought in the diffusion of copper to the surface.—J. G. W.

Some Effects of Minor Elements on the Characteristics of Plain Carbon Steels. F. W. Boulger. (*United Nations Economic Commission for Latin America Conf. on the Iron and*

Steel Industry in Latin America, Bogota, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.75). [In English]. The effects of sulphur, phosphorus, and nitrogen on the properties of low and medium carbon steels are described.—V. G.

High Alloy Castings in Heat-Treating Equipment. (*Steel Processing*, 1953, **39,** Nov., 601–603). The corrosion and heat-resisting alloys of chromium–nickel–iron, recognised as the 'H' series of the American Alloy Casting Institute, are briefly discussed. Typical applications and performances relating to recuperators, annealing retorts, and muffle sections, are described.—P. M. C.

High Alloy Castings Reduce Steel Plant Maintenance. (*Iron Steel Eng.*, 1954, **31,** Apr., 132–138). This article describes individual applications illustrating in detail how cast high-alloy steels are meeting the new demands of the steel industry. Examples include soaking-pit covers, furnace dampers, skid rails, radiant tubes in sheet and bar annealing, as well as a variety of applications in wire mills and metal recuperators.

High-Strength Low-Alloy Steels. (*Mat. Methods*, 1954, **39,** Feb., 117–132). The steels known as high-strength, low-alloy steels are finding wide application in those fields where a reduction in weight or increased corrosion resistance means a considerable saving both in original and operating costs. This article gives the compositions and properties of a selection of such steels and discusses their general characteristics, corrosion resistance, special service properties, joining and working characteristics, applications, economies of use, and design considerations. (22 references).—P. M. C.

A Little Carbon Goes a Long Way. H. K. Ihrig and J. T. Jarman. (*Steel*, 1954, **134,** Mar. 22, 96–97). The influence of carbon and heat-treatment on the properties of iron and steel is briefly considered.—D. L. C. P.

High-Carbon, High-Speed Steels. (*Tecn. Industr.*, 1954, **32,** Jan.-Feb., 82). [In Spanish]. Brief notes on the properties and how to determine them are given.—C. B. L.

High-Tensile Steel Bolts for Structural Joints. (*Engineer*, 1954, **197,** Mar. 19, 415–417 ; Mar. 26, 453–455). This article deals with the properties of high tensile steel bolts, nuts, and washers recently introduced in the place of rivets, describes a representative fastening method, and outlines a number of applications to railway bridges and other structures.

Study of the Watch-Spring Material (I). T. Mitsuhashi and M. Ueno. (*Tetsu to Hagane*, 1951, **37,** Oct., 524–527). [In Japanese]. A report is given on the effects on hardness, tensile strength, elongation, fatigue limit, and torque properties of martempering, austempering, and oil quenching and tempering watch-spring steel.—K. E. J.

Study on the Spring Materials (III). H. Hotta. (*Tetsu to Hagane*, 1951, **37,** Aug., 478–481). [In Japanese]. Experiments on two varieties of spring steel explored the change of hardness under heat-treatment, forgeability, microstructure, and compression strength. By correct heat-treatment, a W–Cr steel was shown to have properties equivalent to those of a W–Cr–V high-speed steel.—K. E. J.

On the Recent Spring Steel. M. Uchiyama. (*Tetsu to Hagane*, 1951, **37,** Jan., 45–56). [In Japanese]. In the post-war years spring steel has become one of the most important special steels in Japan. To aid high-quality production, data on spring steels from British, American, and German sources have been collected ; these cover their development, composition, properties, heat-treatment, and methods of working. (57 references).—K. E. J.

METALLOGRAPHY

Microscopes and Microscopic Techniques. G. K. T. Conn. (*Inst. Metallurgists*: "*The Microscopy of Metals*," 1953, 3–23). The author discusses the principles, applications, and limitations of microscopic techniques with particular reference to optical reflecting, flying-spot, electron, and field emission microscopes. The techniques of micro-beams are mentioned but not discussed. It is concluded that : (1) In recent years advances in microscopy have brought practical advantages in the reflecting microscope and in the use of phase contract and of polarized light ; (2) the principles incorporated in the "flying-spot" microscope are of great versatility, and (3) the development of the reflecting electron-microscope has opened up the application of electron-microscopy to problems such as the effects of strain or of thermal treatment. (31 references).—L. E. W.

General Metallography. H. Evans. (*Inst. Metallurgists*: "*The Microscopy of Metals*," 1953, 24–60). The author first traces the history of microscopy and then discusses the preparation of specimens for microscopical examination with notes on mounting, grinding, polishing, and etching techniques. A table of electrolytes and operating conditions recommended for the electrolytic polishing of some common materials is given. He concludes by discussing in detail the applications of the conventional metallographic techniques, taking as examples a number of ferrous and non-ferrous alloys, and steels, for which photomicrographs and microradiographs are included. The effects of non-metallic inclusions, mechanical and thermal treatment, straining, and corrosion are shown.

The Use of Polarized Light in Metallography. B. W. Mott. (*Inst. Metallurgists*: "*The Microscopy of Metals*," 1953, 61–90). The theoretical considerations involved in the use of polarized light are presented and an attempt is made to show the varied uses to which polarized light metallography can be directed. The methods of rendering isotropic metals reactive to polarized light and the precautions to be observed in the preparation of anisotropic specimens are discussed. The information that can be derived from polarized light metallography is indicated and notes are included on the identification of intermetallic phases and non-metallic inclusions, and on recrystallisation and transformation studies at elevated temperatures. (38 references).—L. E. W.

Hot Stage Microscopy. P. J. E. Forsyth. (*Inst. Metallurgists*: "*The Microscopy of Metals*," 1953, 91–107). The preparation of specimens, and the apparatus required for hot stage microscopy are described in some detail. The microscope may be a standard type capable of accommodating the small furnace. For magnifications up to 250 diameters an ordinary 16 mm. objective is suitable but for higher magnifications a reflecting type objective with a numerical aperture of 0·65 can be used. Due allowance must be made in interpreting the observations for surface effects, and preliminary comparisons are necessary. The technique is considered useful for investigating recrystallization and grain-growth.

Phase-Contrast and Interference Metallography. D. McLean. (*Inst. Metallurgists*: "*The Microscopy of Metals*," 1953, 108–132). The theory of phase-contrast is presented, and the optical equipment and variable phase-contrast arrangements are described. Specimen preparation, the range of operation of the phase-contrast technique, and its uses in metallurgical work are discussed. The author then introduces the principles of interference, describes the experimental arrangements for interference microscopy, and discusses and illustrates the application of the technique. It is concluded that phase-contrast microscopy has wider application than interference microscopy, but that the latter is of particular use in problems which can be settled by an appeal to surface contour, such as studies of plastic deformation and roughness. (14 references).—L. E. W.

Methods and Instruments for Photomicrography on Small Negatives. K. Diebold. (*Acta. Techn.*, 1953, **7,** (3–4), 341–357). [In German]. Apparatus and methods used in photomicrography on small negatives are described in detail, including a method for increasing the lighting of enlarging apparatus.

An Impression Process for Use with the Electron Microscope. R. Bernard and S. Bernard. (*Compt. Rend.*, 1954, **238,** Jan. 11, 222–224). A solution of Plexiglass in trichlorethylene (360 mg. per litre) is poured over the specimen surface which, after drying, gives a film 0·06–0·09 mm. thick. This is detached and covered with a film of silica by evaporation under vacuum, after which the Plexiglass is dissolved with trichlorethylene and acetone. Examples of the results obtained are given.—A. G.

An Automatically Recording Densitometer. Å. Grudemo. (*Appl. Sci. Res.*, 1954, **4B,** (1–2), 3–9). The principle and construction of an instrument for recording photographic density distribution are described in detail. The density of points along a line on the moving film is continuously balanced against a grey wedge by means of a servo-system. The instrument is suitable for all types of X-ray, electron diffraction, and light spectrum photographs.—E. C.

How to Use Micro-Interferometry As a New Chemical Engineering Tool. R. E. Sugg. (*Chem. Eng.*, 1954, **61,** Mar., 216–217). Examples of the use of micro-interferometry are cited and brief particulars of an instrument using collimated monochromatic green light filtered from a mercury vapour lamp are given.—R. A. R.

Fine Interaction in X-ray and Electron Diffraction Photographs. G. D. Archard. (*Brit. J. Appl. Phys.*, 1954, **5,** Jan., 19–22). Theoretical considerations and practical measurements on plates and films agree in indicating that corrections are not easily applied for close groups of lines, which should be avoided if precision is important.—J. O. L.

Electron Physics. (*National Bureau of Standards Circular* 527, Mar. 17, 1954). To mark the fiftieth anniversary in 1951 of the establishment of the National Bureau of Standards, twelve symposia were organized. The present volume of 416 pages records the proceedings of the tenth of the series. Electron physics was interpreted to mean the physics of the free electron. Forty-seven papers were presented among which were :

Experimental Study of Limits Imposed by Plural Scattering in Electron-Diffraction Studies. S. G. Ellis. (101–104).

Fundamental Problems of Theoretical Electron Optics. W. Glaser. (111–126).

Concerning Image Formation in the Electron Microscope. H. Boersch. (127–144). [In German].

On a Phase-Contrast Theory of Electron-Optical Image Formation. H. Bremmer. (145–158).

Theoretical Study of Quality of Images. A. Marechal. (159–165).

Electronic Lenses. P. Grivet. (167–196). [In French].

Present Trends in Electron Microscopy. V. E. Cosslett. (291–303).

Microanalysis by Means of an Electron-Probe Principle and Corrections. R. Castaing. (305–308).

Applications of the Electron Probe Microanalyser. R. Castaing. (309–313). The metallurgical applications mentioned are the determination of curves to represent the diffusion of metals into one another, the study of local variations of the concentrations in alloys, and the analysis of precipitates or inclusions of an unknown nature.—R. A. R.

Macro-Etching Process for Iron and Steels. S. Yoshioka. (*Tetsu to Hagane*, 1951, **37,** July, 430–431). [In Japanese]. A new process of etching comprises coating with a copper deposit, amalgamating, and rubbing with a soft cloth. The pattern is durable, shows fine detail, and gives reliable photographs.—K. E. J.

Mechanism of Etching Metals by Ionic Bombardment. G. V. Spivak, I. N. Prilezhaeva and O. I. Savochina. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **88,** (3), 511–514). The mechanism of cathodic atomization of metals in a gas discharge tube and the development of their structure during this process was studied. A three-electrode tube was used for experiments. Details of correct densities and voltages for the individual stages of ionic etching are given. It is concluded that the structural transformations accompanying ionic etching are connected with the processes of sublimation and condensation and can be explained by the theory of formation of ionic and metallic crystals.—V. G.

Development of the Primary Structure of Welds in Low Carbon and Low Alloy Steels by Electrolytic Etching. A. A. Rossohinskii. (*Automaticheskaya Svarka*, 1953, **6,** (1), 52–54). The technique for developing the primary structure of welds in low carbon and low alloys steels by electrolytic etching is described.—V. G.

The Metallurgy and Welding of Ferrous Chain. E. Wood and P. L. Lewis. (*Bull. Inst. Metallurgists*, 1954, **5,** Mar., 5–20). The authors trace briefly the history of wrought iron and discuss its advantages for use in chain. The metallography of wrought iron is covered with special reference to work carried out by the authors on failure by grain boundary carbide precipitation. The merits of steel, alloy steel, and high tensile chains and their common forms of failure are also dealt with. The authors discuss the various welding methods, particularly flash-welding, and conclude by considering briefly the fabrication of, and materials for, anchor cables. (27 references).—L. E. W.

Study on Fibrous Structures of Steel (III). M. Uchiyama. (*Tetsu to Hagane*, 1951, **37,** Apr., 234–238). [In Japanese]. The phenomenon of the critical cooling velocity of ferrite banding appears in the pearlite field of the **S**-curve, and is irreversible. Fibre growth is also irreversible. The primary ferrite banding of free-cutting steel contains MnS inclusions, but these do not affect the artificial secondary banding.

On Spheroidizing of Carbide in Steel (II). T. Sato and E. Yajima. (*Tetsu to Hagane*, 1951, **37,** Feb., 92–96). [In Japanese]. Studies were made on steels of varying carbon content, repeatedly heated and cooled through the A_1 point. Spheroidizing of cementite was complete after three cycles for hypo-eutectoid, and five cycles for hyper-eutectoid steel. A formula giving the final hardness is terms of carbon content is deduced ; this is higher than is found in spheroidized steel originating from a lamellar pearlitic structure.—K. E. J.

The Wüstite Phase in Partially Reduced Hematite. G. Bitsianes and T. L. Joseph. (*Trans. Amer. Inst. Min. Met. Eng.*, 1954, **200:** *J. Met.*, 1954, **6,** Feb. Section 1, 150–153). The authors have observed an unusually wide band of wüstite in a partially reduced cylinder of chemically pure hematite. X-ray analysis coupled with the results of other workers shows that lattice parameter decreases and oxygen content increases across the wüstite field. The work confirms the existence of four well-defined phase layers in samples partially reduced with hydrogen. The results of a microscopic examination are presented.—G. F.

A Method of Measuring Grain Size and Its Application. W. Dickenscheid. (*Métaux–Corrosion–Indust.*, 1954, **29,** Jan., 14–23). The A.S.T.M. method of measuring grain size and the work of Kostron and Dederichs are first considered. Full details of a new method developed by the author are given together with some of the results obtained. The method uses a series of charts on which are ruled squares and rectangles of different sizes ; the variation in the sizes being a geometrical progression with a common ratio of 1·33. The new technique enables not only the average grain size but also the distribution of grain size to be determined.—B. G. B.

Low-Temperature X-Ray Goniometer for Structural Studies of Crystal Transitions. R. Keeling. B. C. Frazer, and R. Pepinsky. (*Rev. Sci. Instruments*, 1953, **24,** Dec., 1087–1095). This goniometer is designed for use between liquid nitrogen temperature and −100° C. The crystal is mounted inside a Dewar, and can be used with a camera or Geiger counter system.—L. D. H.

Imperfections in Matter. G. W. Rathenau. (*Philips Techn. Rev.*, 1953, **15,** Oct., 105–113). The concept of an ideal or perfect state is prompted by a desire for simplicity which, it would appear, is not shared by nature. The author elaborates on this theme and describes its application to the special field of lattice imperfections and the structure of solids. (27 references).—P. M. C.

Dependence of the Quantitative Composition of a Phase on the Ratio of Atomic Radii on One Class of Intermetallic Phases. P. I. Kripyakevich. (*Doklady Akademii Nauk*, S.S.S.R., 1952, **85,** (2), 321 ; *Fulmer Research Inst. Ltd., Translation No.* 47). [In Russian]. Phase compositions for a number of intermetallic lattices, including that of W_6Fe_7, are considered in terms of atomic radii and co-ordination numbers.—S. K.

A Thermal Gradient Method for the Study of Crystal Structure and Its Application to Order-Disorder Research. J. B. Newkirk. (*Rev. Sci. Instruments*, 1953, **24,** Dec., 1116–1121). Long wire specimens are held at a known temperature gradient, quenched, and examined at room temperature by means of X-ray diffraction.—L. D. H.

Self-Operating Single-Crystal Furnace. W. H. Bridges, G. P. Smith, and J. V. Cathcart, (*Rev. Sci. Instruments*, 1953, **24,** 1149–1150). An apparatus is described for growing single crystals from a slowly cooled melt ; the instrument is self-operating, and economical in construction and maintenance costs. Temperature is controlled automatically, and the furnace moves relatively to the mould to create the necessary temperature gradient.—L. D. H.

Liquid Metal Heat-Transfer Device for Melting High-Purity Materials. F. H. Horn and R. L. Neubauer. (*Rev. Sci. Instruments*, 1953, **24,** Dec., 1154–1155). The crucible is surrounded by a liquid metal, which is heated by induced high-frequency currents. Good heat transference, efficient regulation and freedom from contamination are obtained.

Thermodynamic Functions of Elements and Compounds: Entropies of Inorganic Substances. E. T. Turkdogan and J. Pearson. (*J. Appl. Chem.*, 1953, **5,** Nov., 495–504). The standard entropies of solid elements and inorganic compounds have been related to atomic or molar volumes after grouping the substances according to periodic classification, compound type, and crystal structure. It is shown that, within each sub-group, standard entropy and molar volume are related by the expression $S = aV^n$. For elements and simple compounds the entropy increase between 298° K., and the melting point is related parabolically to the respective temperature rise. The entropy increase for complex compounds is lower

and dependent on the type of compound. Entropy of fusion is related to temperature in the same manner. It is indicated that the entropy of formation of solid products from solid reactions is directly proportional to the volume change during the reaction.—J. O. L.

Energy of Anisotropy and Magnetic Hardness of Monocrystalline Magnetite. H. Danan. (*Compt. Rend.*, 1954, **238**, Mar. 22, 1304–1306). The internal tensions present in natural magnetite crystals influence the values of magnetic hardness which are markedly different in directions of easy and difficult magnetization. No simple relationship was observed.—A. G.

Paramagnetism and the Electron Distribution in the Compounds $NiAl_3$, $CoAl_4$, $FeAl_3$, $MnAl_6$, and $CrAl_7$. G. Fo3x and J. Wucher. (*Compt. Rend.*, 1954, **138**, Mar. 22, 1281–1283). Measurements of the variation of magnetization with temperature have been made to determine the valency state of the metal combined with aluminium. In $FeAl_3$ the iron behaves as if it is a negative monovalent ion.—A. G.

Effect of Nitrogen on the Surface Tension and Crystallization of Austenitic Steel. N. S. Kreshchanovskiĭ, V. I. Prosvirin, and R. P. Zaletaeva. (*Liteĭnoe Proizvodstvo*, 1954, (1), 23–24). [In Russian]. In the investigation described, the surface tension of an austenitic Cr–Ni–Mo steel containing nitrogen in various concentrations (0·02 to 0·23%) was studied by measuring the maximum pressure in a gas bubble. Measurements were made at a temperature of 1500 ± 10° C., and it was found that the surface tension increased from 1100 to 2500 dynes/cm. with nitrogen increasing from 0·02 to 0·23%. The effect of nitrogen on the primary crystallization of the steel was shown to be negligible by comparison with the macrostructures of nitrogen-free and nitrogen-containing (0·23%) castings produced in specially shaped moulds. Neither grain size nor the depth of the columnar crystallization zone were significantly different in the two cases.—S. K.

On the Strength of Solid Solution Alloys. J. C. Fisher. (*Acta Met.*, 1954, **2**, Jan., 9–10). [In English]. Short range order is shown to contribute to the strength of high-alloy solid solutions. Because motion of a dislocation through such a crystal partially destroys this order, an additional stress is required to move the dislocation along the slip plane.—A. D. H.

Solubility of Carbon in Ferrite. M. Hillert. (*Acta Met.*, 1954, **2**, Jan., 11–14). [In English]. The solubility of graphite in ferrite has been calculated from that of cementite in ferrite. Comparison of the two functions reveals that the entropy of formation of the substance with which the solution is in equilibrium influences the absolute value of the solubility.

The Formation of Mechanical Twins. B. A. Bilby and A. R. Entwisle. (*Acta Met.*, 1954, **2**, Jan., 15–19). [In English]. It is suggested that the nucleation of mechanical twins is controlled by large stresses set up locally around various homogeneities in a crystal. The stress fields arising from two types of homogeneity formed during the plastic deformation of an hexagonal metal crystal are considered and it is shown that twin nuclei are unlikely to be formed on planes containing the slip direction of the dislocations in the homogeneity. Available data are compared with the theory and critical experiments are suggested to distinguish between this hypothesis and that which proposes a critical resolved stress.

Slip Planes and the Energy of Dislocations in a Body-Centred Cubic Structure. N. K. Chen and R. Maddin. (*Acta Met.*, 1954, **2**, Jan., 49–51). [In English]. The radio of Burgers vector to the interplanar spacing is derived for $\{112\}$ and $\{123\}$ planes assuming an alternative $\{110\}$ slip process.

Coherent Growth of Martensite During Tempering. T. Ko. (*Acta Met.*, 1954, **2**, Jan., 75–79). [In English]. Martensite plates in a 1·5%-C, 5%-Ni steel are shown to thicken or grow into bainite during tempering. The author suggests that: (*a*) This supports his view that the reduction in volumetric strain by the removal of carbon as carbide provides part of the additional driving force for the coherent growth of bainite; and (*b*) the γ-martensite interface remains coherent after the development of a martensite plate has ceased.

Subcritical Decomposition of Carbide Phase in Some Low-Carbon Silicon Steels. E. D. Harry. (*J. Iron Steel Inst.*, 1954, **178**, Oct., 109–112). [This issue].

The Crystallography of Martensite Transformations I. J. S. Bowles and J. K. Mackenzie. (*Acta Met.*, 1954, **2**, Jan., 129–137). [In English]. The authors discuss the relation between the main geometrical features of martensite transformations and develop a hypothesis on this basis. It is considered that the atomic displacements can be described by homogeneous strain of the parent structure followed by a strain which is part of a twinning shear in the final structure, occurring inhomogeneously. The homogeneous strain is such that all lines in the habit plain are unrotated.—A. D. H.

The Crystallography of Martensite Transformations II. J. K. Mackenzie and J. S. Bowles. (*Acta Met.*, 1954, **2**, Jan., 138–147). [In English]. The hypothesis advanced in Part I is expanded to enable the total strain and all geometrical features of the transformation to be calculated.—A. D. H.

The Crystallography of Martensite Transformations III. Face-Centred Cubic to Body-Centred Tetragonal Transformations. J. S. Bowles and J. K. Mackenzie. (*Acta Met.*, 1954, **2**, Mar., 224–234). [In English]. The theory presented in Parts I and II is applied to transformations from face-centred-cubic to tetragonal lattices in Fe–C, Fe–Ni and Fe–Ni–C alloys. Comparison with available experimental data gives satisfactory agreement.—A. D. H.

CORROSION

Cathodic Protection for Steel Mill Grounding Systems. J. F. Headlee. (*Iron Steel Eng.*, 1954, **31**, Mar., 113–115). The author describes the design and installation of the grounding systems at the Fairless Works of the United States Steel Corp., which presents a typical case of cathodic protection of grounding systems against the galvanic current type of corrosion.—M. D. J. B.

Cathodic Protection with Galvanic Anodes. W. Rausch. (*Metall*, 1954, **8**, Mar., 199–202). The principle of cathodic protection is explained, particularly with reference to its application to ferrous pipe installations. Materials for the anode are considered and the performance of the magnesium anode is examined. Applications are described for protection against corrosion in the soil, by sea water, and by cooling water in oil refineries.—J. G. W.

Corrosion of Steel Piles. I. T. Rosenqvist. (*Tekn. Ukeblad*, 1954, **101**, Mar. 25, 237–243). [In Norwegian]. Steel piles are used for structural foundations in Oslo, but the clay soil is very aggressive, with salt contents of 2–38% (as NaCl). Where soil *p*H is less than 7, the piles must be clad with concrete. The cheapness and reliability of cathodic protection for such piles are stressed. Details are given of the corrosion mechanism, soil studies in the Oslo area, *p*H measurements, and possible errors.—G. G. K.

The Action of Crude Gas on Mild Steel. L. A. Ravald. (*Corrosion Prevention and Control*, 1954, **1**, Apr., 89–94, 104). A description is given of recent research on the interaction of coal gas and steel. A diagram of the laboratory apparatus for the exposure of specimens to attack by corrosive solutions is included and the results are presented in graphical and tabular form. Aqueous hydrogen sulphide was not severely corrosive towards mild steel in relatively oxygen-free conditions, and corrosion by hydrogen cyanide and ammonium thiocyanate need not be serious except on exposure to air. No serious general corrosion of the interior of iron or steel gas plant occurs at normal temperatures prevailing in the wet purification processes but damage occurs if the unit is opened to air. Carbon dioxide did not increase the corrosion, and steel was not attacked by cyanide in the continuous presence of sulphide within the range of *p*H 5 to 7·5. Surveys of gas streams indicated that the liquors and condensates, except oxide purifiers, have *p*H values between 8·8 and 9·5, in which range their attack on steel is small in the absence of air.

The Mechanism of Stress-Corrosion. (*Corrosion Prevention and Control*. 1954, **1**, Apr., 95–97, 99). A description is given of a continuing investigation on the mechanism of stress-corrosion at the U.S. National Bureau of Standards. New data on some of the mechanical and electro-chemical phenomena involved are presented.—L. E. W.

What We Know about Stress Corrosion Cracks in Compressor Blades. R. B. Johnson, jun. (*S.A.E. J.*, 1953, **61**, Dec., 28, 29). Tests on 12% chromium steel strip bent to various degrees and subjected to 50% HCl and 1% SeO_2 solution indicate that the stress level has to be greater than 50,000 lb./sq. in. to cause cracking. Other tests show that blade hardness below 30 Rockwell C tends to insure against stress corrosion cracking.—P. M. C.

Vapour Phase Corrosion Inhibitors. I. D. G. Berwick and B. H. Levelton. (*Eng. J.*, 1954, **37**, Feb., 128–131). The

mechanism of vapour phase inhibition is described, and details are given of the principal compounds, *viz.* amine nitrites, organic esters, and amine carbonates. Paper impregnated with benzoates serves a similar purpose. Principles of selection, and typical applications (*e.g.*, automobile parts, internal surfaces of aircraft engines, ordnance equipment, and machinery) are discussed. (15 references).—K. E. J.

Machine Tool Corrosion by Soluble Cutting Oils. W. Hewett, H. C. Holmes, and J. C. Zelenka. (*Product Finishing*, 1953, **6**, Dec., 82–86 ; 1954, **7**, Jan., 74–86). The corrosion of cast irons used in machine tool construction by eleven soluble cutting oils containing steel turnings has been studied. Clear soluble oils generally showed less corrosive effect than milky fluids but considerable differences were detected by visual and ' Talysurf ' examination. The corrosion depends largely on the combined action of metal chips and the emulsion, and the removal of metal chips after use is recommended.

The Inhibition by Quinolines and Thioureas of the Acid Dissolution of Mild Steel. T. P. Hoar and R. D. Holliday. (*J. Appl. Chem.*, 1953, **3**, Nov., 502–513). Measurements of corrosion rate, corrosion potential and relevant polarization curves show that the attack of 5% H_2SO_4 on mild steel is inhibited by quinolines and thioureas. The former are primarily anodic inhibitors but give cathodic protection at higher concentrations, the latter are more effective and work in the reverse order. Results at 40° and 70° C. are interpreted and discussed in the light of modern theories.—J. O. L.

Behaviour of Galvanized Steel in Sodium Benzoate Solution. P. T. Gilbert and S. E. Hadden. (*J. Appl. Chem.*, 1953, **3**, Dec., 545–548). During experiments on the behaviour of galvanized steel in sodium benzoate solution, it was found that bare steel edges rusted heavily. Electrochemical measurements showed that, in certain circumstances, steel became anodic to zinc. Possible reasons for this behaviour are discussed.—J. O. L.

Corrosion by Petrol and Chlorinated Hydrocarbons. W. Katz and J. Sonntag. (*Metall*, 1954, **8**, Mar. 203–205). Investigations of the relative merits of aluminium and zinc coatings on steel sheet as corrosion inhibitors show that the zinc coating is inferior with regard to moist petrol, with lead tetraethyl, but there is no significant difference in the absence of lead-tetraethyl. The same is true of some chlorinated hydrocarbons, which also tended to increase the corrosion.—J. G. W.

Contribution to the Study of the Effect of Acetic Acid on Cutlery Steel Containing 13% Chromium. R. Blanchard. (*Bull. Cercle Etudes Mét.*, 1953. **6**, Dec., 201–217). The results of a detailed investigation into the corrosion of 13% chromium steel, which is used for cutlery, by acetic acid, are given and discussed. Samples of the steel were subjected to a variety of heat-treatments and corrosion in a solution of 5 g. acetic acid in 100 g. of water at 20° C. studied. The corrosion of 13% chromium steel in sulphuric acid was also studied. Certain samples developed cracks and photomicrographs showing the structures of these samples are reproduced and discussed.—B. G. B.

The Use of Organic Protective Coatings in Controlling Corrosion. E. G. Bobalek. (*Corrosion*, 1954, **10**, Feb., 73–81). Paint binders with high chemical resistance and good inhibitive pigments have been developed independently but are difficult to combine. Organic coatings can be applied as prefabricated liners or liquid coatings. Modern methods of application are critically surveyed. The mechanisms of corrosion prevention are described. Special problems arise with containers for strong acids or alkalis and when coating underground pipe. The use of bituminous, thermoplastic, and thermosetting resin coatings for pipe protection are discussed.

A Systematic Study of Paints for Protection Against Atmospheric Corrosion. M. Van Rysselberge and D. Bermane. (*Peintures–Pigments–Vernis*, 1953, **29**, Dec., 984–999).

Corrosive Attack by Acidic Decomposition Products Evolved by Paints While Drying. A. L. Glass and D. L. Dorfman. (*Corrosion*, 1953, **9**, Oct., 344). Cadmium-plated steel stored in painted wooden boxes corroded. Tests indicated that volatile organic products from the freshly applied paint caused the attack.—J. F. S.

Paint *vs.* Corrosion—Some Aspects of the Problem in the Gulf Coast Area. V. B. Volkening. (*Corrosion*, 1954, **10**, Feb., 63–69). The author poses the corrosion problems encountered by a chemical company. Paints used and testing procedures are described. Skilful paint application is deemed important.—J. F. S.

The Protective Action of Pigments on Steel. M. J. Pryor. (*J. Electrochem. Soc.*, 1954, **101**, Mar., 141–148). The action of aqueous extracts from litharge, lead, red lead, white lead, zinc and ZnO on the corrosion of steel has been investigated. Litharge extracts inhibited corrosion but the others had a lesser or no effect. Litharge, lead, and Pb_3O_4 extracts protected the steel only in aerated solutions. The passive film formed with litharge extracts was mainly of γ-Fe_2O_3. Ions of $Pb(OH)^+$ are considered to be present in litharge extracts whereas those from lead contain massive and colloidal lead hydroxide.—A. D. H.

ANALYSIS

A Rapid and Accurate Technique for the Determination of Tin in Tinplate. C. Courty. (*Chim. et Ind.*, 1954, **71**, Feb., 270–272). This new technique consists of two stages : (*a*) solution in the cold of the tin, almost alone, in hydrochloric acid (density 1·1566) containing 20 g. of antimony trichloride per litre ; and (*b*) iodometric determination of the tin. Both operations occupy only a few minutes.—A. G.

The Determination of Nickel in Nickel Plating Solutions Using Disodium Ethylene-diamine Tetra-Acetate. K. E. Langford. (*Electroplating*, 1954, **7**, Feb., 46–48). Using murexide (ammonium purpureate) as an indicator, volumetric methods for the determination of nickel in the presence of cadmium, magnesium, and cobalt are given. The method is accurate for control purposes.—A. D. H.

The Determination of Boric Acid in Nickel Plating and Acid Zinc Plating Baths by Means of Cation Exchangers. G. Gabrielson. (*Plating*, 1954, **41**, Jan., 47–53). Details are given of the use of a cation exchanger of strongly acid type in the hydrogen form to remove nickel, zinc and other interfering ions. The maximum error of the method is $\pm 0{\cdot}5\%$.

The Colorimetric Determination of Zinc in Effluents. R. F. Muraca, D. G. Gardner, and E. J. Serfass. (*Plating*, 1954, **41**, Feb., 155–163). The method employs dithizone as the colour-forming reagent after elimination of interfering elements with cupferron extraction, and complexing with cyanide and thiosulphate. The method is satisfactory in the range of 5–50 p.p.m. Zn in the presence of 100–5000 p.p.m. of 25 ions in a simultaneous mixture. The procedure can be modified for contents of 0·01–1·0 p.p.m. Zn, and modified procedures are given when the amounts of materials other than zinc are known.—A. D. H.

Substitutes for the Zimmermann-Reinhardt Reagent in the Determination of Iron in Hematite and Magnetite Ores. K. M. Somasundaram and C. J. Suryanarayana. (*Proc. Indian Acad. Sci.*, 1954, **39**, Jan., 41–43). The authors describe the analytical procedure and discuss the results obtained. They found that : (1) Sodium acetate and borax, which are good substitutes for the Zimmermann–Reinhardt reagent in pure solutions of ferrous ammonium sulphate with hydrochloric acid, are inefficacious when dealing with extracts from hematite and magnetite ; (2) acetates of NH_4^+, Li^+, K^+, Ca^{++}, Ba^{++}, Sr^{++}, Zn^{++}, Mg^{++}, Hg^{++}, Cd^{++}, Sn^{++}, Al^{+++}, Ce^{++++} and VO_2^{++}; borates of NH_4^+, K^+, Mn^{++}, Ba^{++}, Ca^{++}, Mg^{++}, Sr^{++}, Al^{+++} and Zn^{++} ; potassium biphosphate, sodium pyrophosphate, trisodium phosphate, potash alum, aluminium chloride, potassium hydrogen sulphate, and ammonium sulphate are not useful substitutes for the Zimmermann-Reinhardt reagent ; and (3) manganous acetate under identical conditions is as effective as the Zimmermann-Reinhardt reagent, and potassium sulphate is even better.—L. E. W.

Rapid Determination of Phosphorus in Ferro-Manganese. T. Ikegami and N. Nagaoka. (*Tetsu to Hagane* 1951, **37**, 107–108). [In Japanese]. Phosphorus in ferromanganese may be determined in approx. 10 min. Details of the procedure are given ; it depends on the formation of the molybdate complex and centrifuging at 2000 r.p.m. to give a consolidated and measurable volume of precipitate.—K. E. J.

Analysis of Hydrogen in Cast Iron. T. Kinoshita and T. Hara. (*Tetsu to Hagane*, 1951, **37**, Feb., 102–107). [In Japanese]. Experiments showed that a useful comparative method for hydrogen content could be based on vacuum extraction at 900° C. Application of this indicated higher hydrogen contents in iron from the electric furnace (compared with the cupola) and in irons of low silicon content.—K. E. J.

Flame Photometric Determination of Alkali and Alkaline Earth Elements in Cast Iron. D. F. Kuemmel and H. L. Karl.

(*Analy. Chem.*, 1954, **26**, Feb., 386–391). A flame photometric method has been developed for the simultaneous determination of calcium, magnesium, sodium, and lithium in cast irons. After solution in HCl and filtration of insoluble matter, the bulk of the iron is removed by ether extraction. The acqueous extract is examined with the flame photometer by the standard procedure.—A. G.

Spectrographic Determination of Certain Rare Earths in Stainless Steels. E. W. Spitz, J. R. Simmler, B. D. Field, K. H. Roberts, and S. M. Tuthill. (*Analy. Chem.*, 1954, **26**, Feb., 304–307). A D.C. arc spectrographic method is described which, after suitable electrochemical and chemical separations, can determine down to 50 mg. total rare earths in a 1-g. sample of steel. The accuracy is assessed at $\pm 10\%$.

HISTORICAL

The Quality of Toolsteel—Historical Development. B. George. (*Metal Progress*, 1954, **65**, Feb., 97–100). An historical survey of the development of tool steels to the present day is presented.—B. G. B.

Charcoal Blast-Furnace Operation in the Dill Region 100 Years Ago. R. Herwig. (*Stahl u. Eisen*, 1954, **74**, Feb. 11, 230–231). The profile and construction of a blast furnace at Dillenburg, which operated until 1898, is described. During the period 1862–1864, for which records are available, the daily output of iron was about 5 tons per day.—J. P.

From the Noric Iron Age to the Roman Times. (*Werkszeitung der Schoeller-Bleckmann Stahlwerke*, 1952, **19**, (1), 7–10; (3), 7–8). A brief historical account is given of the Noricum district from about 800 B.C. to A.D. 100 with special reference to the ironmaking for which it was then famous. Noricum is a district south of the Danube, corresponding approximately to what is now Styria and Carinthia.—R. A. R.

Reasons for the Development in the Loire Basin of High Quality Steel Production. J. Seloron. (*Arts et Manuf.*, 1954, Jan., 51–54). An historical survey of the development of the steel industry in this district of France to the present day is presented.—B. G. B.

The Evolution of the Iron and Steel Industry. G. Décamps. (*Arts et Manuf.*, 1954, Jan., 38–41). A short historical survey of the evolution of the iron and steel industry in Europe is given; this includes the development of the open-hearth, Bessemer and basic-Bessemer processes. Recent advances in basic-Bessemer practice (*e.g.*, oxygen-enriched blast, double slag) are discussed.—B. G. B.

Iron, Steel, and American History. E. N. Hartley. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1953, 11–27). This article deals mainly with the XVIIth Century ironworks at Sargus in Massachusetts, and describes the building on the original site of a replica of this pioneer plant.—G. F.

ECONOMICS AND STATISTICS

Iron and Steel Industry in 1953. (*Metal Age*, 1954, Jan., 3–5). The steel statistics for 1953 are briefly reviewed. The European steel output was slightly higher in 1953 than in 1952 and reached 15 million metric tons (excluding U.S.S.R.).

World Steel Production. (*Brit. Iron Steel Fed. Monthly Stat. Bull.*, 1954, **29**, Feb., 9–11). Statistics of world steel production in 1953 are given. The prewar and postwar production are compared and changes in the regional totals and future plans are discussed.—V. G.

The European Export Entente. (*Brit. Iron Steel Fed. Monthly Stat. Bull.*, 1954, **29**, Feb., 5–8). The export price agreement for steel by producers in the countries belonging to the European Coal and Steel Community and the views of the High Authority on this matter are outlined.—A. G.

Coming Changes in Iron and Steel. C. E. Sims. (*Batelle Tech. Rev.*, 1954, **3**, Jan., 7–8). The demand for finished iron and steel products is expected to increase over 50% during the next 25 years. A corresponding increase in supply of iron ore is envisaged. A promising future is forecast for the surface-blown basic converter. Greater use of electric furnaces is advocated, particularly for the production of low-alloy and carbon steels.—R. P.

The Iron and Steel Industry in the Countries of the British Commonwealth. W. Lauersen. (*Z.V.d.I.*, 1954, **96**, Jan. 11, 50–57). Postwar structure, size, and developments of the steel industry in Canada, Australia, India and Pakistan, and the Union of South Africa, are described by reference to UNESCO and French Statistics, and the prospects of the Iron and Steel Community entering Commonwealth markets in competition with Japan and the United States are examined.

Britain and the E.C.S.C. (*Brit. Iron Steel Fed. Monthly Stat. Bull.*, 1954, **29**, Mar., 5–9). The relationship between the British steel industry and that on the Continent before 1939 is outlined. The implications of partial or complete participation of Britain in the European Coal and Steel Community are discussed.—V. G.

Steel Scrap. (*B.H.P. Rev.*, 1953, **30**, Sept., 1–3). The importance of steel scrap to the Australian steel industry, and the necessity for maintaining adequate supplies are stressed. The major users of scrap in Australia are the open-hearth furnaces at Newcastle and Port Kembla. It is estimated that in 1954 the combined steel scrap requirements of the Newcastle and Port Kembla Works will be 700,000 tons.—L. E. W.

The Steel Industry's Coal. (*Brit. Iron Steel Fed. Monthly Stat. Bull.*, 1954, **29**, Apr., 5–6). The implications for the steel industry of the recent coal price increases (May 1954) are outlined.—V. G.

The World Wide Development of Electric Steelmaking over the Last 50 Years. R. Sevin. (*Arts et Manuf.*, 1954, Jan., 42–46). The increasing use of electric furnaces, both arc and induction, for steelmaking, over the last 50 years is discussed. Examples of modern furnaces are described.—B. G. B.

Steelmaking in Lorraine. M. Grison. (*Arts et Manuf.*, 1954, Jan., 47–50). The dominating part which the Lorraine district plays in the French steelmaking industry is shown by the fact that in July 1953, 75 out of a total of 89 blast-furnaces and 25 out of a total of 70 open-hearth furnaces were in the Lorraine district, and 65% of the steel, 93% of the ore, and 78% of the pig iron were produced in Lorraine. Details of the development and present state of the industry are given.

Norway's Metal Industries. (*Metal Age*, 1954, Feb., 3–6, 8). The salient features of the production of ores and metals in Norway during 1950–1952 are reviewed. The dependence of the metal industries on electric power is stressed. Ferro-alloys are the main export and the total production is now about 230,000 tons a year and exports 150,000 tons. Since 1953 exports of all types of ferro-alloys, except ferrosilicon, have fallen off. The Norwegian steel industry can at present supply only about 20% of its own domestic steel requirements. Most of the electric pig iron produced is exported and the present maximum capacity is 50,000 tons. The new Mo-i-Rana plant of A/S Norsk Jernverk will ultimately be the largest pig iron producer with a capacity of 200,000 tons.

Yugoslavia's Mineral Wealth—Largest Producer of Non-Ferrous Ores in Western Europe. (*Metal Age*, 1952, Dec., 3–7, 14). The salient features of Yugoslavia's mineral wealth and metallurgical industries are briefly reviewed, and several tables of Trade Statistics for the period 1939–1952 are included. Yugoslavia possesses a small but expanding iron and steel industry. Production in 1952 was at the annual rate of 300,000 tons pig iron and 450,000 tons of crude steel, and of the former, the Bisak blast-furnaces in Croatia produced 125,000 tons.—L. E. W.

The Russian Iron and Steel Industry—Targets for the Fifth 5-Year Plan. N. T. Gudtsov and L. N. Roitbur. (*Iron Steel*, 1954, **27**, Apr., 153–154). A brief outline is given of the targets of the fifth five-year plan for the Russian iron and steel industry. The target outputs of pig iron, steel, and rolled products respectively are 176%, 162%, and 164% of the 1950 totals, and the general development and the measures recommended to achieve these increases are summarized.—G. F.

Preliminary Information Regarding Costs of Several Factors of Interest to the Iron and Steel Industry. Secretariat of the Economic Commission for Latin America. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogotá, Colombia, Oct. 13–Nov. 5, 1952, Paper L.89). [In English]. The approximate costs of labour, various fuels, power and the range of iron and steel products in Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela are compiled.—V. G.

Consumption of Iron and Steel Products in Mexico. Marcelo G. Aramburu. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*. Bogotá, Colombia, Oct, 13–Nov. 5, 1952, *Paper* L.83). [In English].

Some Suggestions for Increasing the Iron and Steel Industry in Latin America. Pablo Sada. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel*

Industry in Latin America, Bogotá, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.84). [In English].

Factors Influencing Iron and Steel Consumption in Latin America. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogotá, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.86). [In English].

Influence of Local Factors on the Iron and Steel Industry in Latin America. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogotá, Colombia, Oct.13–Nov. 5, 1952, *Paper* L.87). [In English].

The Iron and Steel Producing and Transforming Industries in the Economics of Latin America Countries. (*United Nations Economic Commission for Latin America Conf. on the Iron and Steel Industry in Latin America*, Bogotá, Colombia, Oct. 13–Nov. 5, 1952, *Paper* L.88). [In English].

Economic Survey of Seven Methods of Making Small Machine Parts. S. Storchheim. (*Metal Progress*, 1954, **65,** Feb., 77–80). The seven methods discussed are gravity die casting, die casting, precision investment casting, screw machining, stamping, extrusion, and powder metallurgy. The cost of each method is considered.—B. G. B.

MISCELLANEOUS

Water Supply for Steel Plants. R. Nebolsine. (*Iron Steel Eng.*, 1954, **31,** Apr., 78–88). The author describes the important role of water supply in the steel industry and discusses the water demands of integrated steel plants. The principal features of the water systems used, utilization of the available supply, quality of water, and plant distribution systems are dealt with. Various types of water extraction installations, depending on the available sources of supply are illustrated and engineering factors for water supply expansion are reviewed.—M. D. J. B.

Foundation Design for Iron and Steel Plants. G. S. Richardson. (*Iron Steel Eng.*, 1954, **31,** Apr., 73–76). The author discusses the determination of safe soil bearing loads and safe pile loading, and concludes that point bearing piles can be designed to carry very heavy loading with safety, that pile seating must be checked by tests and that although settlement will occur, it can be kept down to very low values.

German Metallurgists' Visit to Steelworks and University Metallurgy Departments in the Soviet Union. W. Küntschner. (*Met. u. Giesserei Techn.*, 1954, **4,** Feb., 49–54). This is a general report of the visit to the U.S.S.R. of 30 East German metallurgists in September and October 1953. Reference is briefly made to coking plants, blast-furnaces, open-hearth furnaces, Bessemer steelworks, rolling mills, and to university teaching.—L. J. L.

John Summers & Sons Limited—Services. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 66–70). This description of the services on the new plant of John Summers & Sons Ltd. covers water, heat insulation, low-pressure steam, compressed air, blast-furnace and coke-oven gases, and tar and fuel oil. Laboratory services are also listed.—G. F.

John Summers & Sons Limited—General Instrumentation. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 72–75). The instrumentation discussed in this article on the new plant of John Summers & Sons Ltd. includes the blast-furnace platform panel and pyrometer house, sinter plant, gas-cleaning plant, the blower house, fuel control office, waste-heat boilers, coke-oven plant, and water metering. The indications and recordings made in each case are noted.—F. G.

John Summers & Sons Limited—Traffic Operation. (*Iron Coal Trades Rev. Special Issue*, 1953, Apr. 20, 95–99). This article describes the re-organization of transport arrangements made necessary by the recent extensions to the Shotton works of John Summers & Sons Ltd. The re-organization includes a new marshalling and holding yard.—G. F.

John Summers & Sons Limited—Metallurgical and Chemical Control. (*Iron Coal Trades Rev. Special Issue*. 1953, Apr. 20, 99–102). This article traces metallurgical developments which have been made at John Summers & Sons Ltd. to meet the changing conditions and new demands both at home and abroad, and discusses the closer metallurgical and chemical control now adopted.—G. F.

John Summers & Sons Limited—Central Engineering and Maintenance Shop. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 103). An illustration is shown of the new central engineering and maintenance shop of John Summers & Sons Ltd.—G. F.

John Summers & Sons Limited—Welfare. (*Iron Coal Trades Rev., Special Issue*, 1953, Apr. 20, 103–105). The working of the general welfare scheme at John Summers & Sons Ltd. is illustrated by descriptions of some characteristic functions, including accident prevention, works transport, and sickness benefits.—G. F.

Research—One of the Factors in the Industrial Success of the United States of America. G. Delbart. (*Fonderie*, 1954, Jan., 3745–3754). The organization of research and development in the United States of America is outlined and the attitude to industrial research is compared with that existing in Europe.—B. C. W.

Education and Training in the Iron and Steel Industry. (*Brit. Iron Steel Fed. Fifth Training Conf,*. Ashorne Hill, Oct. 15–17, 1952). The following titles of addresses to this Conference, which was sponsored by the Training Committee of the British Iron and Steel Federation, were :

Progress Report 1952. C. H. T. Williams. (5–13).
Production and Training. C. H. T. Williams. (14–18).
Training in Accident Prevention. (19–28).
Can Man Management Be Taught? G. E. D. Halahan. (29–35).
What Should Supervisors Be Taught, and How? J. D. Alford, T. Griffiths, and W. D. Hargreaves. (37–40).
The Centre d'Etudes Supérieures de la Sidérurgie (C.E.S.S.I.D.). M. Lefèvre-Rigot. (41–46).

Education and Training for Management in the Iron and Steel Industry. (*Brit. Iron Steel Fed. Sixth Training Conf.*, Ashorne Hill, Oct. 21–23, 1953). Sixty companies as well as universities, university colleges, and technical colleges were represented at this conference by 190 delegates. This report contains the following papers :

Progress Report 1953. C. H. T. Williams. (7–15).
Immediate Problems in Management Training. N. R. R. Brooke. (16–22).
The Development of Future Managers—Works Experience. W. F. Cartwright. (23–29).
The Development of Future Managers—Outside Studies. F. H. Perkins. (30–37).
The Universities and Industry To-Day. C. I. C. Bosanquet. (38–44).
Management Problems in a Developing Industry. Sir Andrew McCance. (49–54).

T.V., Can It Help the Steel Industry? (*Brit. Steelmaker*, 1954, **20,** Apr., 126–128). The industrial potentialities of television are outlined and the closed circuit commercial television system developed by Pye Ltd. is briefly described. Its use for the control of dangerous processes and as an educational aid is discussed, and actual service installations in America are mentioned.—G. F.

BOOK NOTICES

ATKINS, W. A. "*Practical Sheet and Plate Metal Work.*" By the late E. Arthur Atkins; 6th edition by W. A. Atkins. 8vo, pp. ix + 498. Illustrated. London, 1954: Sir Isaac Pitman and Sons, Ltd. (Price 30*s.*)

This book is a revised edition of a volume which has been widely used for many years. The text has been modified where necessary to include modern methods of manufacture, and it can fairly claim to illustrate present-day practice. All diagrams and illustrations have been redrawn with quite pleasing results and should be easily read and understood by the craftsman and student.

It is essentially a reference book for the sheet-metal worker, who will find within its pages many drawings and illustrations showing methods of producing the developments of surfaces of a great variety of shapes found in this class of work.

This book should also prove very useful to students and apprentices studying for examinations in sheet and plate

metal-work, whilst the teacher of practical geometry will find it a fruitful source of practical examples in his subject.

The first 36 chapters deal in detail with the manufacture of a great number of articles produced from flat sheets or plates, amongst which may be mentioned tee-pieces, bends, hoods, conical articles, cornices, ventilators, hoppers, tanks, and shells.

Two chapters are devoted to the methods of making joints in sheets and plates, and special attention is given to the production of riveted joints for pressure vessels.

Useful practical information is given in the remaining chapters on the ways by which metal corrosion can occur, and how it may be prevented by proper treatment of the surfaces.

Brief explanations of the properties of various metals are also included, as are short descriptions of annealing and welding.

In a book which is so complete in many parts it is to be regretted that so little information is included on the welding of sheets and plates.—C. E. DEAR.

BAILEY, A. R. "*A Text-Book of Metallurgy.*" 8vo, pp. viii + 560. Illustrated. London, 1954: Macmillan and Co., Ltd. (Price 30*s.*)

The aim of the author has been to provide in one volume of roughly 500 pages a general account of the extraction of metals, their refining, fabrication and heat-treatment, and of general metallography. This is clearly an ambitious project, and the book must be considered in relation to it. The first six chapters (175 pages) are concerned with the metallographic section and give a good general picture of this field. It must always be a matter of opinion what material to include, and a still more difficult question what to leave out, but such matters as the dislocation theory and the electron microscope are included perhaps at the expense of a more solid treatment of fundamentals.

The remainder of the book is concerned with the more practical aspects of metallurgy, commencing with a discussion of ores and ore preparation. An interesting chapter discusses the general principles of extraction and refining metallurgy, which is followed by one in which copper, zinc, lead, nickel, tin, aluminium and magnesium are separately considered. It is clear that to deal with the extraction and refining of these seven metals in 40 pages means that only the barest outlines can be given. Chapter 10 is concerned with the production of iron and steel, and in 42 pages the whole story from the ore to the steel ingot is discussed. This is followed by a chapter dealing with alloying and casting, in which a good account is given of casting techniques and the defects from which castings and ingots may suffer. Mechanical working, powder metallurgy and welding are then discussed. The two final chapters are concerned with mechanical testing and the measurement of temperature. In an appendix the equilibrium diagrams of some of the more important systems are reproduced, and the book finishes with a large number of questions which have been set in representative examinations. After each chapter a list of references suitable for further study is given.

The book is most clearly written and is well illustrated, and, given the general aim of the author, is distinctly successful. As a general introduction to metallurgy there is probably no volume in which the general problem has been more satisfactorily solved, but it *must* be remembered that a book of this kind must inevitably contain an element of the superficial. To the reader, therefore, who wishes to obtain a general introduction to the whole field of metallurgy, this book will appeal, but few readers, except possibly those concerned with general metallography, will find more than this.—F. C. THOMPSON.

BRAY, JOHN L. "*Ferrous Production Metallurgy.*" 8vo, pp. ix + 414. Illustrated. New York, 1954: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd. (Price 52*s.*).

A comprehensive book of reasonable size on the production of iron and steel is always useful, especially if it is written, as this book is, for student use. The late Professor Bray had already written one such book. The present one is naturally more up-to-date, contains less background material, but invokes more physical chemistry.

The arrangement of the subject matter follows a fairly normal order. The first chapter deals with the raw materials, including iron ores, and their preparation. The treatment of the latter aspect is rather specific and restricted in content. It could profitably be made wider in scope and more detailed. This chapter also deals briefly with coals and their coking for the blast-furnace, fluxes, and the characteristics of the air.

The next chapter covers the blast-furnace and the production of pig iron, together with the appropriate auxiliary operations, ferro-alloy production and other methods of iron production. Then follows a short chapter on the manufacture of wrought iron.

The Bessemer steelmaking process is next dealt with. In this there is little reference to the ordinary basic process, although basic side-blown converters are discussed. Open-hearth steelmaking occupies two chapters, the main one of these applying to the basic process and including short sections on the appropriate fuels and refractories. The subsequent chapter describes the acid open-hearth process. Chapter 7 is concerned with arc furnaces for the production of steel and ferro-alloys, and with the induction furnace. The final chapter gives a useful account of ingots and ingot moulds.

In the above treatment a number of recent developments are described. To mention the use of oxygen, operation of the blast-furnace with high top pressure, the use of radioactive tracers in investigating ferrous processes, and the continuous casting of steel will indicate the author's efforts to bring the reader into touch with recent trends. However, as far as can be seen, the book does not include one reference to further reading ; and, the student studying iron and steel production to any advanced level will certainly need such references, not only to recent developments but to the whole field. It seems only fitting that the author should make some suggestions.

For the illustrations the author has followed his normal practice of employing well-made line drawings and making no use of photographs. The reviewer has no disagreement with such practice in a book of this character.

To conclude, it can be stated that this volume provides a very useful general account of the title matter, although this has received something of an American bias. It is written in a clear and easily assimilated style.—A. R. BAILEY.

DAVIES, OWEN L. (Editor). "*The Design and Analysis of Industrial Experiments.*" Authors: George E. P. Box, Lewis R. Connor, Wilfred R. Cousins, Owen L. Davies, Francis R. Himsworth, George P. Sillito. La. 8vo, pp. xiii + 637. Illustrated. London and Edinburgh, 1954: Oliver and Boyd. (Price 63*s.*)

This is the second excellent book edited by Dr. Owen L. Davies and produced under the auspices of Imperial Chemical Industries, Ltd., and, although complete in itself, it is a sequel to the first book published in 1947. It has been written by a team of chemists and statisticians, and deals comprehensively with the application of modern statistical methods to the design and analysis not only of laboratory experiments but also of experiments carried out on production plants.

After the first short introductory chapter, the second chapter deals with the planning of simple comparative experiments, it being assumed that the circumstances are such that it is necessary to plan the experiment completely in advance and then apply an appropriate statistical test when all the observations have been collected. Such tests are called " non-sequential " to distinguish them from the " sequential " tests which are discussed in the third chapter, and which are applied to the data as each observation is recorded. It is pointed out that, when observations are obtained one after another, it is generally possible to adopt a procedure in which, after each observation is made, a simple statistical test is applied to determine whether the results obtained so far indicate a definite conclusion or whether more observations are needed to make the experiment decisive. Consequently the sequential method has definite advantages, particularly when the experiments are expensive or time-consuming. Chapter 4 deals with the investigation of sampling and testing methods and shows how experiments should be so arranged that the overall variation can be analysed to show the variation arising from different sources, such as the various stages of sampling and testing, the differences between the batch of samples and the different operators, methods of analysis, etc.

Chapter 5 introduces the reader to Randomized Blocks and to Latin Squares. Whereas Chapter 5 deals with the straightforward comparison of a number of treatments such as different heat-treatments or different solvents, Chapter 6 is concerned with cases where experimental conditions do not permit blocks large enough to include every treatment, so that all treatments cannot be tested under uniform conditions.

The next four chapters deal with the elementary principles of factorial experiments, with factorial experiments with factors at more than two levels, with confounding in factorial designs, and with fractional factorial experiments, and the book concludes with a chapter devoted to the determination of optimum conditions, *i.e.*, with the problem of finding the best operating conditions for a process by maximizing some feature such as the yield or purity of the product, or minimizing the cost. One is therefore inclined to say that this is the most important chapter of all, but one wants to say the same about every chapter.

This book requires reading with care, but it does not call for a knowledge of advanced mathematics, and practically all physicists and plant engineers will, if they read with care, be able to understand and to apply its teachings. A particularly useful feature is the way in which each technique is illustrated by well chosen samples covering such subjects as abrasion resistance of rubber, an inspection scheme for primers for explosives, a comparison of precision of two methods of analysis, an investigation into synthetic fibre strength, an investigation into the dyeing properties of yarn, the manufacture of an organic chemical, the corrosion resistance of aluminium alloys, the yield of penicillin, etc.—J. FERDINAND KAYSER.

KRONIG, R. (Editor). "*Textbook of Physics.*" Under the editorship of R. Kronig in collaboration with J. de Boer, H. C. Burger, P. H. van Cittert, C. J. Gorter, A. C. S. van Heel, P. van der Leeden, G. J. Sizoo, with biographical notes and tables by J. Korringa. First published in the Dutch language in 1946; first English edition translated from the third Dutch edition of 1951. La. 8vo, pp. xv + 855. Illustrated. London, 1954: Pergamon Press, Ltd. (Price 70*s.*)

This is a really fine effort to unite in a single volume all that a student (or some students) of physics needs to know. Naturally, it does not pretend to state everything that is known in physics, but it does claim to sketch out the whole field, and to do this in an orderly manner, avoiding repetition as far as this is possible. Consequently, it should be thought of first as a text book, but it will often be useful as a reference work, both to physicists and to others whose main interest lies outside physics.

The standard aimed at is a fairly advanced, but not the most advanced, level. Thus, in the chapters dealing with mechanics, the equations of motion of rigid bodies are set down, and gyroscopic motions are considered, but there is no reference to general dynamics, in which the motions are determined from the energies, expressed in any co-ordinates, by means (preferably) of Hamilton's equation. A student who intends to go into the modern quantum theory will have to fill this gap later.

Throughout the book, the practical applications of physics are kept in mind; thus, still in the chapter on mechanics, there are paragraphs on kinematical mechanisms, including journal bearings. Incidentally, on p. 60, the author seems to accept without any word of warning, the method of support which consists of three screws fitting into three holes. There is a chapter on vibrations and waves, but practically nothing about sound in its modern aspects.

Electrical theory is well done, and the practical man is remembered again when A.C. theory is treated, for the use of vector diagrams in this subject is described and its advantages are pointed out. The treatment is quite up-to-date and includes a fairly full account of wave guides. There is an unfortunate misprint on page 192, where the mass of the electron is said to be "09107×10^{-30} kg.," and the reader has to guess that the decimal point has been omitted after the zero and not before it. On the same page, a few lines higher, 10^{-9} should be 10^{-19}.

The treatment of physical optics seems to the reviewer to be the best part of the book, though he is no specialist in this subject.

Readers of this *Journal* will note with special regret that there is nothing about the electron theory of metals; the name of Brillouin occurs only once in the book, and then in another connection altogether.

The book was written in Dutch by a team of eight authors, and has been translated very well into English; but surely the translator will blush when he realizes that he has allowed "The efficiencies of both lamps are about 15 and 3 lumens per watt respectively" to appear! His readers will be surprised to read on p. 668 that "getters are sublimated in the tube." On p. 203, *boussole* means *tangent galvanometer*, and on page 204 the translator has set a puzzle for the young student by confusing non-magnetic bodies with unmagnetized bodies—a very different thing. However, in such a long book, these are minor blemishes.

For a unified, logical and modern account of the fundamental parts of physics, this book is excellent value.—J. H. AWBURY.

PHYSICAL SOCIETY. "*Reports on Progress in Physics.*" Vol. XVII, 1954. Executive Editor, A. C. Stickland. La. 8vo, pp. [iv +] 280. Illustrated. London, 1954: The Society. (Price 50*s.*).

In the seventeenth volume of these reports, which is shorter than some of its predecessors, the well-known standard is maintained. They deal with physics at all dimensional scales, from the structure of the nuclear shell, through diffraction theory, atmospheric electricity, movements in the ionosphere, to the condition of the solar corona, and conclude with the theory of the origin of cosmic rays, which involves consideration of conditions in gaiaxies beyond our own. The metallurgist will find little of direct application in his own work, but much that can extend his understanding of physical processes.—J. P. S.

THOMPSON, HENRY. "*Microscopical Techniques in Metallurgy.*" 8vo, pp. xii + 146. Illustrated. London, 1954: Sir Isaac Pitman and Sons, Ltd. (Price 18*s.*).

This modest little book has a misleading title. The microscopical techniques with which the work is concerned are based upon a description of the design and adjustment of the metallurgical microscope which is covered in four pages of text; while half the book (some seventy pages), is devoted to a survey of microstructures of metals in general and to their interpretation. Indeed the book is intended as a simple introduction to the methods for preparing metals for microscopic examination with explanatory notes on the interpretation of characteristic structures rather than as a work on the techniques of the microscope as applied to opaque surfaces.

The opening chapters describe the procedures for sampling, mounting, and polishing metal specimens. The methods of electropolishing and the reagents used in etching are then outlined, references being given at the end of each chapter to the more specialized aspects of these techniques. There follows a very abbreviated description of the metallurgical microscope; this is very surprising in view of the advances in design of standard equipment which have taken place in recent years. No reference is made to the improvements in polarized light technique nor to the provision of equipment for phase contrast and interference microscopy which have made the metallurgical microscope an even more flexible and useful tool. Although the bibliography includes references to these techniques several important recent books are omitted. The reflecting systems which permit long working distances for hot-stage investigations are unmentioned.

In contrast the author describes in detail the photographic process and the making of photomicrographs, in particular, a chapter is devoted to the processing of colour photographs. This welcome feature does, however, emphasize the absence of any earlier discussion of the use of polarized light where colour refinements would be of advantage. The remainder of the book is concerned with the methods for determining flake and grain sizes and to a survey of common microstructures. Standard charts for the determination of oxide and silicate inclusion ratings are reproduced. A considerable number of photographs are included to illustrate the characteristic appearance of the constituents of steels, copper alloys, bearing bronzes, and the alloys of aluminium, magnesium, and lead. As an introductory and brief reference monograph for students the price is somewhat high at 18*s.*—J. HOLDEN.

AMERICAN IRON AND STEEL INSTITUTE. "*Carbon Steel Sheets.*" (Steel Products Manual). Revised June 1954. 4to, pp. 65. Illustrated. New York, 1954: The Institute.

AMERICAN IRON AND STEEL INSTITUTE. "*Annual Statistical Report*, 1953." 8vo, pp. 116. New York, 1954: The Institute.

'*A.S.M. Review of Metal Literature.*" An Annotated Survey of Articles and Technical Papers Appearing in the Engineering, Scientific and Industrial Journals and Books, Here and Abroad, Received in the Library of Batelle Memorial Institute, Columbus, Ohio. Volume 10, 1953. 8vo, pp. x + 711. Cleveland, Ohio, 1954 : American Society for Metals. (Price 116*s.*)

AMERICAN SOCIETY FOR TESTING MATERIALS. "*Symposium on Fretting Corrosion.*" Presented at the Fifty-Fifth Annual Meeting (Fiftieth Anniversary Meeting), American Society for Testing Materials, New York, June 25, 1952. (ASTM Special Technical Publication No. 144). 8vo, pp. [iv +] 84. Illustrated. Philadelphia, 1953: The Society. (Price $2.75)

BRITISH STANDARDS INSTITUTION. B.S. 2455: 1954. "*Methods of Sampling and Testing Boiler Water Deposits.*" 8vo, pp. 45. London, 1954. The Institution. (Price 6*s.*)

BRITISH STANDARDS INSTITUTION. B.S. 2486: 1954. "*Treatment of Water for Land Boilers.*" 8vo, pp. 38. London, 1954: The Institution. (Price 6*s.*)

BRITISH STANDARDS INSTITUTION. "*British Standards Institution Yearbook*, 1954." 8vo, pp. iii + 508. London, 1954: The Institution. (Price 12*s.* 6*d.*)

BUTTRESS, F. A. "*World List of Abbreviations of Scientific, Technological and Commercial Organizations.*" 8vo, pp. ix + 261. London, 1954 : Leonard Hill, Ltd. (Price 18*s.*)

CHALMERS, BRUCE, and R. KING. "*Progress in Metal Physics.*" Volume 5, 1954. La. 8vo, pp. vii + 324. Illustrated. London, 1954: Pergamon Press, Ltd. (Price 60*s.*)

COHEN, MORRIS (Editor). "*Dislocations in Metals.*" 8vo, pp. viii + 200. Illustrated. New York, 1954: American Institute of Mining and Metallurgical Engineers, Institute of Metals Division. (Price $5)

CONNELL, VERA. "*The Application of Results of Research.*" (British Commonwealth Scientific Conference). Compiled and edited in collaboration with the British Commonwealth Scientific Offices (London). 8vo, pp. vii + 212. London, 1954: Butterworths Scientific Publications. (Price 21*s.*)

DODD, R. E., and P. L. ROBINSON. "*Experimental Inorganic Chemistry.*" A Guide to Laboratory Practice. Pp. xii + 424. Illustrated. Amsterdam, 1954: Elsevier Publishing Co.; London: Cleaver-Hume Press, Ltd. (Price 42*s.*)

FEIGL, FRITZ. "*Spot Tests.*" Volume I. "*Inorganic Applications.*" Translated by Ralph E. Oesper. Fourth completely revised English Edition. Pp. xii + 518. Amsterdam, 1954: Elsevier Publishing Co., Ltd.; London distributors: Cleaver-Hume Press, Ltd. (Price 45*s.*)

FORBES, WILLIAM GORDON. "*Lubrication of Industrial and Marine Machinery.*" Second edition, revised by C. L. Pope and W. T. Everitt. La. 8vo, pp. 351. Illustrated. New York, 1954: John Wiley and Sons, Inc. (Price $6.50)

GARRETT, C. G. B. "*Magnetic Cooling.*" Pp. xi + 110. New York, 1954 : John Wiley and Sons, Inc. (Price $4.50)

HALLOWS, I. S. (Editor). "*International Review of Metal Finishing.*" 8vo, pp. 170. Illustrated. London, 1954: Sawell Publications, Ltd. (for *Product Finishing*). (Price 10*s.* 6*d.*)

HARTMANN, HANS. "*Georg Agricola.* 1494–1555." Begründer dreier Wissenschaften: Mineralogie—Geologie—Bergbaukunde. (Grosse Naturforscher, Bd. 13.) Pp. 134. Illustrated. Stuttgart, 1953: Wissenschaftliche Verlagsgesellschaft m.b.H. (Price DM 10.80)

INTERNATIONAL UNION OF CRYSTALLOGRAPHY. "*Structure Reports for* 1945–1946." Volume 10. General editor, A. J. C. Wilson; section editors, C. S. Barrett and J. Monteath Robertson. La. 8vo, pp. viii + 325. Illustrated. Utrecht, 1953 : N.V. A. Oosthoek's Uitgevers Mij. (Price Fl. 45, 84*s.*, $12)

KIERSCH, GÜNTHER. "*Internationale Eisen- und Stahlkartelle.*" (Rheinisch-Westfalisches Institut für Wirtschaftsforschung, Essen, Schriftenreihe, N.F. Nr. 4). 8vo, pp. 224. Essen, 1954: Rheinisch-Westfalisches Institut für Wirtschaftsforschung. (Price DM 11.–)

KREKELER, KARL (and JOSEF MENNEN). "*Versuche über die Anwendung der inductive Erwärmung zum Sintern von hochschmelzenden Metallen sowie zur Anlegierung und Vergütung von aufgespritzten Metallschichten mit dem Grundwerkstoff.*" (Forschungsberichte des Wirtschafts- und Verkehrsministeriums Nordrhein-Westfalen. Nr. 47). 4to, pp. 56. Köln, Opladen, 1953: Westdeutscher Verlag. (Price DM 13.90)

KUMANIN, J. B., and A. M. LJASS. "*Kernbinderwerkstoffe.*" 8vo, pp. 256. Illustrated. Berlin, 1953: VEB Verlag Technik. (Price DM 28.–)

LEIKIN. "*Das Schmelzen von Stahl im Elektroofen.*" [Translated from the Russian.] La. 8vo, pp. 396. Berlin, 1953: VEB Verlag Technik. (Price DM 50.–)

MACHU, W. "*Oberflächenhandlung von Eisen- und Nichteisenmetallen.*" Pp. xx + 801. Illustrated. Leipzig, 1954: Akademische Verlagsgesellschaft Geest u. Portig. K.-G. (Price DM 49.–)

MONYPENNY, J. H. G. "*Stainless Iron and Steel.*" Volume Two. "*Microstructure and Constitution.*" Third edition, revised. Edited by Professor F. C. Thompson. 8vo, pp. xii + 330. Illustrated. London, 1954: Chapman and Hall, Ltd. (Price 55*s.*)

MORLEY, ARTHUR. "*Strength of Materials.*" Eleventh edition. 8vo, pp. x + 532. Illustrated. London, New York, Toronto, 1954: Longmans, Green and Co. (Price 21*s.*)

MUSKHELISHVILI, N. I. "*Some Basic Problems of the Mathematical Theory of Elasticity.*" 3rd revised edition. Translated from the Russian by J. R. M. Radok. Pp. xxxi + 704. Groningen, Holland, 1953: P. Noordhoff, Ltd. (Price Fl. 38)

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION. "*The Gasification of Coal.*" Pp. 104. Paris, 1953: The Organisation. (Price 6*s.*)

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION. "The Organisation of Applied Research in Europe, the United States and Canada." (Report of Technical Assistance Missions Nos. 81–82–83.) La. 4to. Volume I. "*A Comparative Study,*" pp. 76. Volume II. "*Applied Research in Europe,*" pp. 183. Volume III. "*Applied Research in the United States and Canada,*" pp. 125, illustrated. Paris, 1954: The Organisation.

PALMER, W. G. "*Experimental Inorganic Chemistry.*" 8vo, pp. xx + 578. Illustrated. London, 1954: Cambridge University Press. (Price 50*s.*)

POLLARD, SIDNEY. "*Three Centuries of Sheffield Steel. The Story of a Family Business.*" La. 8vo, pp. [viii +] 82. Illustrated. Sheffield, 1954: Marsh Brothers and Co., Ltd.

RYDER, G. H. "*Strength of Materials.*" Pp. x + 278. Illustrated. London, 1953: Cleaver-Hume Press, Ltd. (Price 21*s.*)

SCHMID, LEOPOLD. "*Der Bau und der Betrieb der Kupolöfen.*" Bd. 2. T. III. "*Die Rohstoffe und Betriebsstoffe der Kupolöfen.*" T. IV. "*Die chemischen und physikalischen Vorgänge in den Kupolöfenschächten.*" T. V. "*Die Bemessung und der Aufbau der Eisensätze.*" (2. Aufl.) 8vo, pp. 219. Illustrated. Halle/Saale, 1953: Knapp. (Price DM 9.60)

SPLITTGERBER, A. "*Wasseraufbereitung im Dampfkraftbetrieb.*" Ein Handbuch für gewerbliche und industrielle Unternehmer, Konstructeure, Kraftwerks-Chemiker und -Ingenieure, Sachverständige der technischen Überwachung der Gewerbe aufsicht und des Materialprüfwesens. Pp. 430. Illustrated. Berlin, Göttingen, Heidelberg, 1954: Springer-Verlag. (Price DM 48.–)

"*Der Steirische Erzberg und der Bergbau Radmer.*" Ein Führer, herausgegeben von der Oesterreichisch-Alpine Montangesellschaft, Bergdirektion Eisenerz. Sm. 8vo, pp. 67. Illustrated. Eisenerz, Styria, 1952: The Company.

STEWART, K. H. "*Ferromagnetic Domains.*" (Cambridge Monographs on Physics.) 8vo, pp. 188. Illustrated. London, 1954: Cambridge University Press. (Price 25*s.*)

TIMOSHENKO, S. P. "*Collected Papers.*" Pp. xxv + 642. Illustrated. New York, 1954: McGraw-Hill Book Co., Inc. (Price $15)